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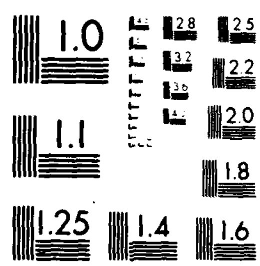

MICROCOPY RESOLUTION TEST CHART

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

PRELIMINARY GEOTECHNICAL INVESTIGATION PROPOSED OPERATIONAL BASE SITE COYOTE SPRING VALLEY, NEVADA

VOLUME I - SYNTHESIS

PREPARED FOR
BALLISTIC MISSILE OFFICE (BMO)
NORTON AIR FORCE BASE, CALIFORNIA

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

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This report presents the results of the preliminary geotechnical evaluation of the proposed Operational Base site in Coyote Spring Valley, Nevada. The purpose of this study was to assess the geological, geophysical and soils engineering data & to present recommendations regarding site suitability, foundations for various facilities, construction considerations, & aggregate resources.

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PRELIMINARY GEOTECHNICAL INVESTIGATION
PROPOSED OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office
Norton Air Force Base, California 92409

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23 December 1980

FUGRO NATIONAL INC

FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL, Item 004A2. It contains a preliminary geotechnical evaluation of the proposed Operational Base (OB) site in Coyote Spring Valley, Nevada. The operational base will support the MX Land Mobile Advanced ICBM System in Nevada and Utah. This report presents geological, geophysical, and soils engineering data as well as recommendations regarding site suitability, preliminary conclusions regarding foundations for various facilities, construction considerations, and aggregate resources.

Concurrent with the study reported herein, two other proposed operational base sites in Utah (Beryl and Milford) are being investigated for the same purpose. Reports on these sites will be issued at a later date. Other studies in progress for the same three operational base sites are water resources, environmental and mineral surveys, and topographic mapping. The results of these studies will be presented in separate reports.

Volume I of this report is a synthesis of the data obtained during the study. Volume II is a detailed compilation of the data generated and used in this investigation.

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EXECUTIVE SUMMARY

The results of the preliminary geotechnical investigation performed at Coyote Spring Valley, Nevada, indicate that the area is suitable for an Operational Base (OB) for the MX system.

The preliminary conclusions and recommendations are as follows:

1. Depth to Rock - Depth to rock in the operational base test and training site, main operational base, and designated assembly area is greater than 150 feet (46 m) except possibly along the extreme eastern margins of these activity centers.

2. Depth to Water - The depth to the water table below all of the planned OB activity centers is greater than 300 feet (91 m). Limited quantities of "perched" ground water may exist locally throughout the site area.

3. Terrain - Terrain in the area of the activity centers is acceptable. A linear belt about 2 miles (3 km) wide trending diagonally through the study area has been delineated because of the incision depth and spacing criteria. Areas with surface gradients exceeding five and ten percent generally occur along the margins of Coyote Spring and Kane Springs valleys.

4. Faults - Potentially active faults trend toward and through the site area. The fault traces and projections of the traces should be avoided for locating structures. Historic seismicity in the site area has been low; however, earthquakes of magnitudes of 6.1 have been recorded regionally. The potential for fault rupture and earthquake hazards should be evaluated in future studies.

5. Flooding - Within the general area of the OB site, the potential for major flooding is relatively low. However, considerable amounts of runoff should be expected in areas where A5y fan drainages occur. It appears that conventional flood control methods would be effective in controlling any flood hazard. The degree and locations of potential flooding should be determined in subsequent studies.

6. Foundations - The foundation soils at the proposed locations of the OB activity centers consist predominantly of dense to very dense sandy gravels which are an excellent foundation bearing material. It is expected that all structures can be supported by a system of shallow spread and continuous footings.

7. Roads and Runway - The gravelly subsoils at the MOB will provide good to excellent support as a subgrade for construction of roads and the runway. Because of terrain conditions at the proposed location, it is recommended that the runway be moved further to the west if possible.

8. Slope Stability - Natural slopes are in stable condition. Temporary cut slopes in gravelly deposits can be made as steep as 1/2:1 (horizontal: vertical) if the materials are cemented. Permanent cut slopes will depend on soil conditions, height of cuts, and degree of cementation and can be expected to vary from 1:1 to 2:1.

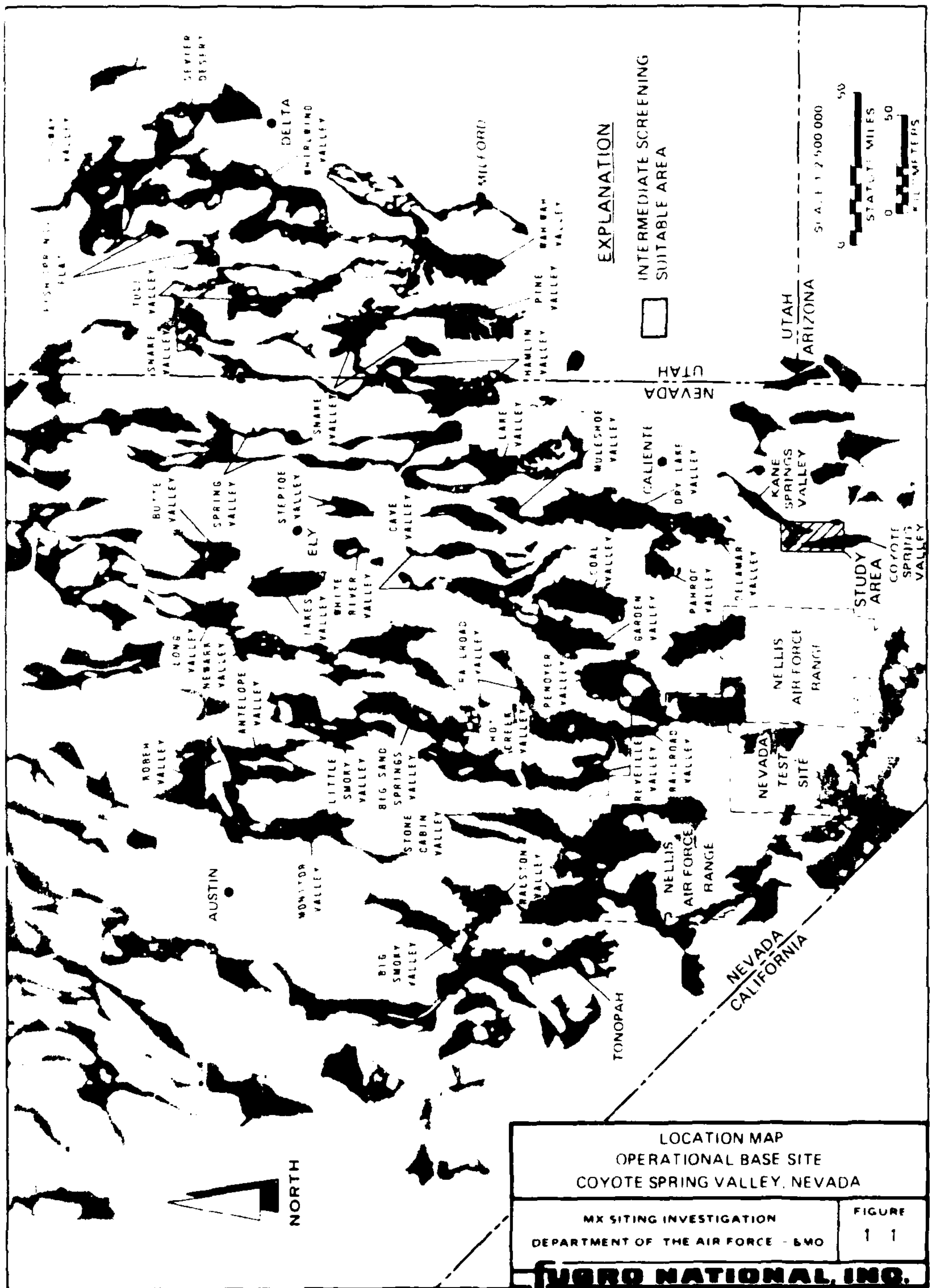
9. Construction Considerations - Conventional equipment can be used for excavation and compaction in the top 5 feet (1.5 m). However, in areas where Stage III and IV caliche exist, ripping and/or blasting may be necessary for excavation. Sulfate attack of lake sediments on concrete will have to be taken into consideration in design of concrete elements exposed to the soil. Most of the gravelly soil will not be susceptible to frost action. Frost action in the finer grained soils or in gravels with a significant amount of fines will be moderate.

1.0 INTRODUCTION

This report presents the results of a preliminary geotechnical evaluation of the proposed Operational Base (OB) site in Coyote Spring Valley, Nevada (Figure 1-1). The purpose of this study was to assess the geological, geophysical, and soils engineering data and to present recommendations regarding site suitability, foundations for various facilities, construction considerations, and aggregate resources.

Our previous report, "Operational Base Site, Coyote Spring and Kane Springs Valleys, Nevada," submitted 27 February 1980, included discussions on water supply, land ownership, existing and proposed transportation systems, and terrain and geotechnical conditions. No field work was conducted for that initial study. Four conceptual layouts were presented in that report for the three major activity centers; i.e., the Main Operational Base (MOB), the Designated Assembly Area (DAA), and the Operational Base Test and Training Site (OBTS). Subsequently, there have been a series of meetings and discussions concerning the location of activity centers within the siting area.

For the present site-specific investigation, the preferred conceptual layouts (as described in Section 2.0) were developed by a working group on operational base siting composed of personnel from SAC, AFRCE, BMO, Fugro National, TRW, Martin Marietta, COE, and the Ralph M. Parsons Company. The geotechnical siting criteria and exclusions which formed a baseline for the present



LOCATION MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 1 1

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study are derived from the document entitled "Siting Criteria for MX Operating Bases, 10 November 1980."

The present report is more detailed than our prior report and is the result of a thorough review of available geotechnical data as well as detailed field studies within the proposed site area. This report contains two volumes; Volume I is a synthesis of the data with conclusions and recommendations, and Volume II is a compilation of the data. This report is intended to be utilized by the architect and engineer for the preliminary layout of facilities within the various activity centers and for preliminary foundation design considerations.

The objectives of this study have been to:

- Identify the geologic units;
- Determine the subsurface conditions and depths to rock and water;
- Characterize the basin-fill deposits and describe the physical and engineering properties of the subsoils in the activity center areas;
- Identify adverse terrain conditions;
- Identify geologic hazards including flooding, faulting, landslides, and subsidence;
- Develop preliminary foundation design recommendations in the activity center areas and general construction considerations; and
- Identify potential aggregate sources.

2.0 SITING CRITERIA AND ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Conceptually, the proposed Operational Base (OB) consists of four main activity centers. Their names and approximate areas are as follows:

Activity Center	Approximate Area acres (hectares)
Main Operational Base (MOB)	1800 (700)
Designated Assembly Area (DAA)	1800 (700)
Operational Base Test and Training Site (OBTS)	2200 (900)
Base Housing (BH)	2700 (1100)

The proposed layouts of these centers at the Coyote Spring Valley site (Figure 2-1), as shown in this report, were developed by the operational base working group on 20 August 1980.

2.1 SITING CRITERIA

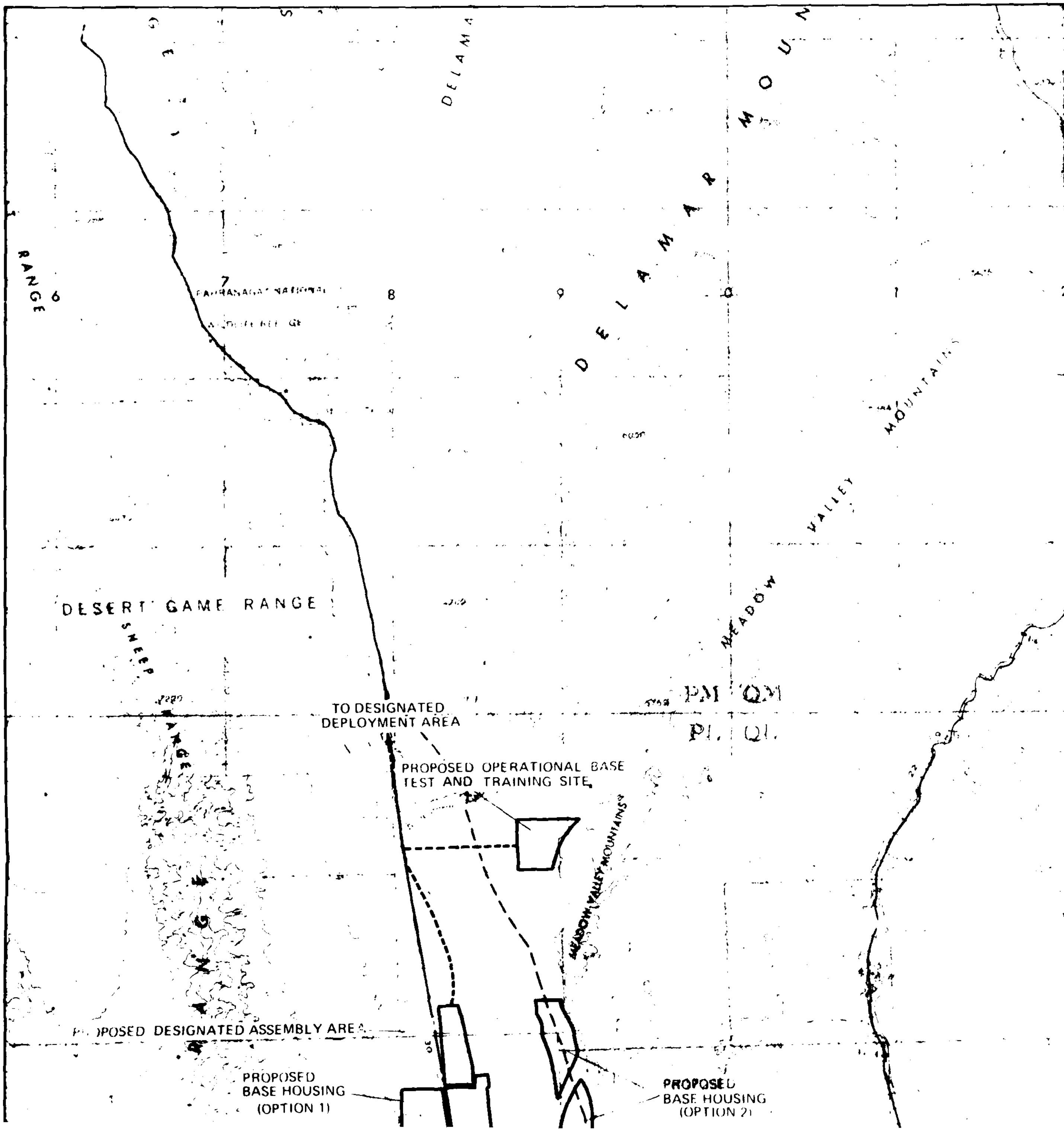
The operational base layout for the proposed Coyote Spring site generally follows the criteria set out in the draft BMO document "MX Siting Criteria for MX Operating Bases, 10 November 1980." In this document, guidelines for siting and exclusion are also provided. Those relevant to the present geotechnical investigation are excerpted below:

Desirable Geotechnical Features

- Suitable soil for building and landscaping; and
- Avoid active and potentially fault zones.

Geotechnical Exclusions

- Areas having rock and water within 50 feet (15 m) of surface except base technical and housing areas (OBTS/Training);



DELAMAR MOUN
DELAMA
DELAMAR
MEADOW VALLEY MOUNTAINS
RANGE
DESERT GAME RANGE
SHEEP RANGE
TO DESIGNATED DEPLOYMENT AREA
PROPOSED OPERATIONAL BASE TEST AND TRAINING SITE
MEADOW VALLEY MOUNTAINS
PM QM
PL QL
PROPOSED DESIGNATED ASSEMBLY AREA
PROPOSED BASE HOUSING (OPTION 1)
PROPOSED BASE HOUSING (OPTION 2)
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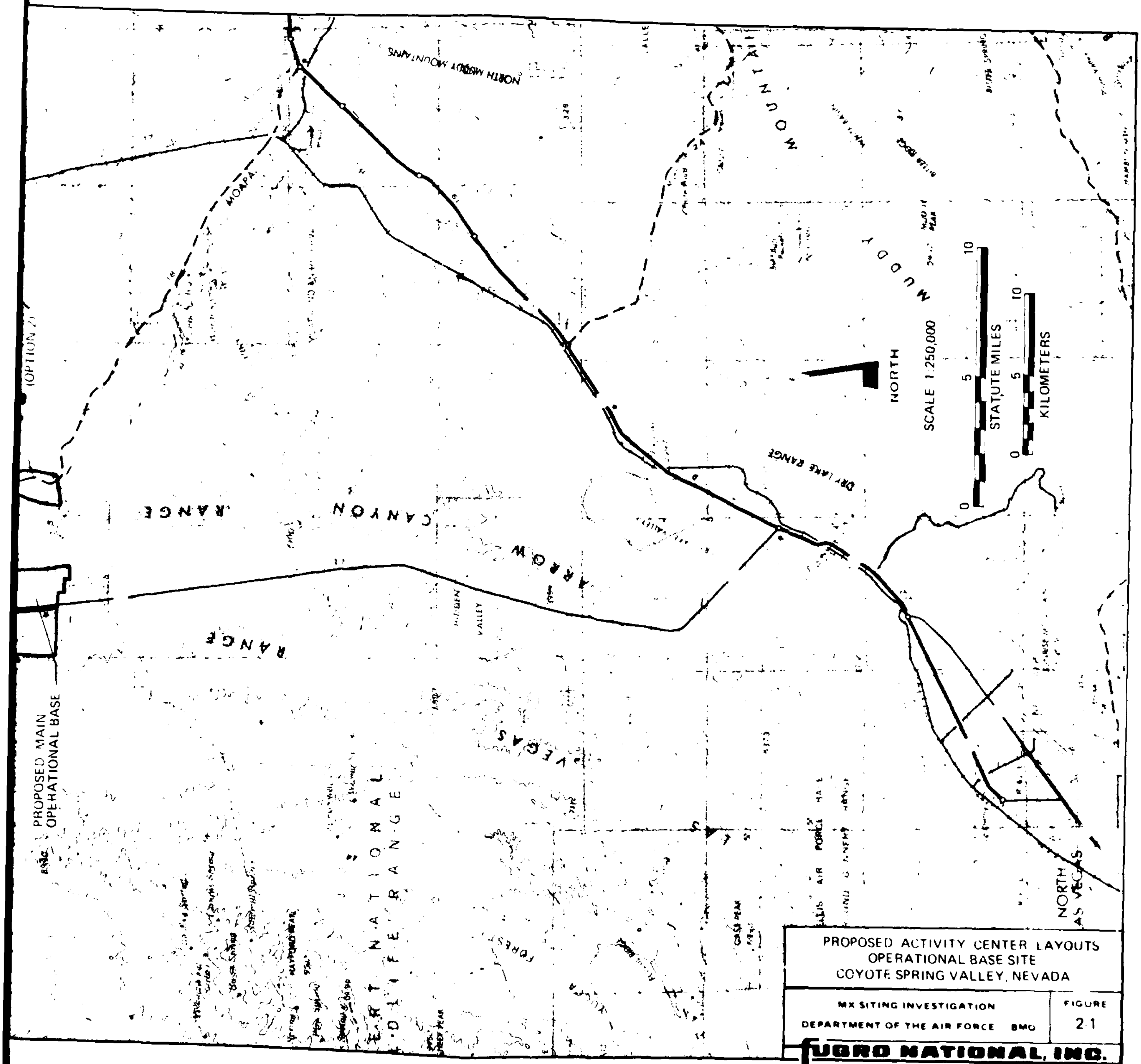

PROPOSED ACTIVITY CENTER LAYOUTS
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 2.1

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2

- Surface grade (DAA/OBTS/Training and Airfield);
  - Nominal surface grade of greater than five percent;
  - Local grade greater than ten percent measured over a 1000-foot (305-m) length;
  - More than two 10-foot (3-m) deep drainage crossings per 1000 feet (305 m); and
- Surface water which includes all significant lakes, reservoirs, swamps, perennial drainages, and playas subject to flooding.

2.2 ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Proposed structures and the estimated column loads, identified in each activity center, are listed below. For discussion purposes, the estimated column loads are categorized into light (less than 50 kips) (23 tonnes), medium (50 to 200 kips) (23 to 91 tonnes), and high (greater than 200 kips) (91 tonnes).

Structures in MOB	Estimated Column Load High (H), Medium (M), or Light (L)
Office (office space for 800 personnel, computer center, and dining space for 1000 people)	M
Shop	L
Communication Tower	H
Fuel Tank	not applicable
Storage Silo	H
Warehouse	L to M
Fire Station	L
Vehicles Maintenance Facility	L
Airport Facility	M
Runway (12,000 feet [3658 m] long)	not applicable
Marshalling Yard	not applicable
Structures in DAA	
Missile Assembly Building (150-ton [136-tonne] bridge crane)	H
Heavy Vehicles Assembly Facility (15-ton [14-tonne] bridge crane)	M

Launcher Assembly Building	M
Launcher Integration Building	M
Stage Storage Area (earth covered structure, 10-ton [9-tonne] overhead crane)	M
Weapon Storage Area	M
Missile Storage Area	M
Warehouse	L to M
Office	L
Laboratory (electronic equipment)	L
Shop	L

Structures in OBTS

Cluster Maintenance Facility Storage	M
Office	L
Laboratory	L
Shop	L

Structures in BH

Residential Houses	L
Apartments	L
Community Center	M
Hospital	M
Recreation Center	M
School	M

These assumptions regarding column loads were used in planning the geotechnical investigations described herein. Additionally, they are a basis for the discussion of Foundation Considerations in Section 6.2.

All the structures except the Missile Assembly Building (MAB) have been assumed to have the lowest floor level at final grade. Only the deeper part of the MAB will have lowest floor level at 50 feet (15 m) below grade.

3.0 SCOPE

The scope of the study consisted of the following:

- Review of existing data;
- Field investigations by geologists, geophysicists, and engineers;
- Laboratory testing on selected samples recovered from the borings, trenches, and test pits; and
- Analysis of the results of the field and laboratory investigations and the subsequent discussions, conclusions, and recommendations.

3.1 REVIEW OF EXISTING DATA

Prior to the geotechnical field activities, existing data were reviewed. The existing data included the results of the previous investigation by Fugro National, Inc. (report dated 27 February 1980, FN-TR-35), other published literature included in the bibliography, land status conditions, and results of geologic investigations in the general vicinity of the site published by the Nevada Bureau of Mines and the U.S. Geological Survey.

3.2 FIELD INVESTIGATION

The field investigation performed in October 1980 consisted of geologic mapping, exploratory borings, trenches, test pits, cone penetrometer tests, and geophysical (seismic refraction and electric resistivity) surveys. The different techniques used in the field investigation are outlined in Table 3-1. Detailed procedures for geologic, geophysical, and engineering activities are included in Sections A2.0, A3.0, and A4.0 of Appendix A, respectively. Table 3-2 lists the types and numbers of the field activities performed.

OBJECTIVES → **VERIFICATION OF SUITABLE AREA FOR ACTIVITY CENTER**

DATA FOR EVALUATIONS → **TERRAIN PARAMETERS** | **GEOLOGIC HAZARDS** | **50'/150' DEPTH TO ROCK**

FIELD TECHNIQUES AND APPLICATIONS →

TERRAIN PARAMETERS

Geologic mapping

- Identification and limits of areas with slopes greater than 5% and 10% grade

GEOLOGIC HAZARDS

Geologic mapping

- Identification of faults and lineaments
- Evaluation of flooding
- Evaluation of rockfall potential

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Depth to rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of high velocity layers from p-wave velocities (> 7000 fps)

Borings

- Occurrence of rock

Existing data

- Published literature

BLE AREA FOR ACTIVITY CENTER LAYOUTS

CHARACTERISTICS OF BASIN FIL

ARDS

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Depth to rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of high velocity layers from p wave velocities (> 7000 fps)

Borings

- Occurrence of rock

Existing data

- Published literature

50'/150' DEPTH TO GROUND WATER

Borings

- Occurrence of ground water

Electrical resistivity seismic refraction surveys

- Provide supplemental data to support presence or absence of ground water

Existing Data

- Published literature

EXTENT AND CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches and test pits

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soil
- Samples for laboratory testing

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties shear strength, compressibility
- Chemical properties

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of so

ROAD AN DESIG

Trenches

Cone penet

Laborat

Exist

CHARACTERISTICS OF BASIN FILL → **PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS**

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocity

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

ROAD AND RUNWAY DESIGN DATA

Trenches and test pits

- Identification of soil types
- In-situ soil density and moisture
- Thickness of low strength surficial soil

Cone penetrometer tests

- In-situ soil strength

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbase or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

Borings

- Subsurface soil types
- Presence of cobbles and boulders
- In-situ density of subsurface soils
- Stability of vertical walls

Trenches and test pits

- Subsurface soil types
- Subsurface soil density and cementation
- Stability of vertical walls
- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of geologic units

Seismic refraction surveys

- Excavatability

FIELD TECHNIQUES
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3.1

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GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	103
Shallow refraction	11
Intemediate refraction	1
Deep refraction	1
Electrical resistivity	5

ENGINEERING–LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	135
Specific gravity	5
Sieve analysis	113
Hydrometer	6
Atterberg limits	34
Consolidation	9
Unconfined compression	11
Triaxial compression	9
Direct shear	67
Compaction	8
CBR	8
Chemical analysis	12

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
2	160 (49)
5	100 (30)
9	50 (15)
NUMBER OF TRENCHES	**NOMINAL DEPTH FEET (METERS)**
14	14 (4)
NUMBER OF TEST PITS	**NOMINAL DEPTH FEET (METERS)**
36	10 (3)
NUMBER OF CONE PENETROMETER TESTS	**NOMINAL DEPTH FEET (METERS)**
39	33 (10)
16	SAME AS NEAREST BORING

SCOPE OF ACTIVITIES,
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 3-2

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Permits for access were arranged through the Las Vegas, Nevada, District Office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few instances where a potential environmental or archaeological disturbance was identified. Brief descriptions of each type of of activity follow.

3.2.1 Geologic Mapping

The primary objectives of the field geologic mapping were to identify any geologic hazards or conditions not identified in previous studies and to delineate and define soil and rock formations. Color aerial photographs (1:25,000 scale) were used as a mapping base. The field data were subsequently transferred to 1:24,000-scale topographic maps.

3.2.2 Borings

Rotary wash techniques were used to drill borings to depths ranging from approximately 50 to 160 feet (15 to 49 m) below the existing ground surface. Both undisturbed and representative soil samples were taken at various depths for laboratory testing.

3.2.3 Trenches and Test Pits

Trenches and test pits were excavated at selected locations throughout the site to determine characteristics of the shallow subsurface soils. Bulk samples were taken for laboratory testing.

3.2.4 Cone Penetrometer Tests (CPTs)

Cone penetrometer tests were performed to supplement borings to obtain continuous soil information and to estimate in-situ soil properties.

3.2.5 Seismic Refraction Surveys

One deep, one intermediate, and 11 shallow seismic refraction surveys were conducted to determine the depth and configuration of subsurface velocity layers.

3.2.6 Electrical Resistivity Surveys

Five resistivity surveys were performed to provide data on the electrical properties of the subsurface soils.

3.3 LABORATORY TESTING

Laboratory testing was performed on representative soil samples to determine the engineering properties of surface and subsurface soils. The testing program included soil classification, moisture/density, Atterberg limits, compaction, California Bearing Ratio (CBR), triaxial shear, unconfined compression, direct shear, and consolidation tests. In addition, chemical tests were performed on representative samples from various soil layers. Testing procedures, which are in general compliance with the ASTM standards, are discussed in Section A4.0 of Appendix A. The number of tests performed is summarized in Table 3-2.

3.4 ANALYSES, CONCLUSIONS, AND RECOMMENDATIONS

Following the field and laboratory investigations, analyses were made of all the collected data. These included studies of land status in the site area, cultural conditions, depths to shallow rock and water, locations of faults and lineaments, and types and properties of surface and subsurface soils. Following the analyses, conclusions and recommendations were developed regarding site suitability, potential geotechnical hazards such as faults, flooding and rockfall, stability of natural and cut slopes, location of potential aggregate sources, types of foundations for the various structures and their allowable bearing pressures, and construction considerations.

4.0 GEOGRAPHIC AND CULTURAL CONDITIONS

4.1 LOCATION

The site area is located approximately 45 miles (72 km) from Nellis Air Force Base, Nevada, and includes the central portion of Coyote Spring Valley and the southwesternmost portion of Kane Springs Valley (Figure 1-1).

Coyote Spring Valley extends approximately 40 miles (64 km) in a north-south direction and has a maximum width of about 8 miles (13 km). The northern portion of the valley is in Lincoln County and the southern portion is in Clark County. The elevation of the valley floor in the site area is about 2250 feet (686 m). On the east, the valley is bounded by, from south to north, the steep fronts of the northern Arrow Canyon Range, southern Meadow Valley Mountains, and the southwesterly tip of the Delamar Range. The Arrow Canyon Range rises a little more than 5000 feet (1524 m) above sea level. The southern Meadow Valley Mountains attain a maximum elevation of about 5500 feet (1677 m) above sea level. On the west, Coyote Spring Valley is bounded by, from south to north, the Las Vegas Range, the Elbow Range, and the Sheep Range. The Las Vegas and Elbow ranges in the site area attain maximum elevations of about 4650 and 3808 feet (1418 and 1161 m), respectively. The crest of the Sheep Range is higher than 7000 feet (2134 m) above sea level, and half of this distance exceeds 8000 feet (2439 m) above sea level. Hayford Peak, altitude 9920 feet (3024 m), at the southern end of the range is the highest point in the area.

Kane Springs Valley extends northeasterly from the northern end of Coyote Spring Valley. It is about 25 miles (40 km) long and up to about 4 miles (6 km) wide. The elevation of the valley floor in the site area is about 2250 feet (686 m) above sea level. Kane Springs Valley is bounded on the northeast by the Delamar Range and on the southeast by the Meadow Valley Mountains. A section of about 4 miles (6 km) along the crest of the Delamar Range is higher than 7000 feet (2134 m). Only a few short segments of the Meadow Valley Mountains in this area are higher than 5000 feet (1524 m) above sea level.

4.2 CULTURAL FEATURES

Cultural features within the site area include paved and unpaved roads, power transmission lines, borrow pits, and the Desert National Wildlife Range (DNWR).

Paved roads within the site area include U.S. Highway 93, "old" Highway 93 (not presently maintained), and State Route 7. U.S. Highway 93 trends north-south along the central portion of Coyote Spring Valley. "Old" U.S. Highway 93 trends northwesterly along the eastern margin of Coyote Spring Valley. State Route 7 trends east-west through the southerly portion of the site. Low wing dikes (generally less than 3 feet [0.9 m] high) constructed of local gravels are located along the eastern side of "old" Highway 93. The main power transmission line of the Lincoln County Power District lies approximately 200 feet (61 m) west of U.S. 93 and generally parallels the highway. The proposed route of the southern California-bound Intermountain

Power Project (IPP) transmission line is planned as far as a mile and a quarter (2.1 km) to the east. Power transmission lines also trend northeasterly across the southerly portion of the site. The DNWR is located west of U.S. Highway 93. No structures or fences are associated with the wildlife range. At the time of our field investigation, an east-west trending barbed wire fence located approximately 4 miles (6.4 km) north of Highway 7 was under construction.

4.3 LAND STATUS

Coyote Spring and Kane Springs valleys contain mostly public lands administered by the BLM, Las Vegas District Office. There are 1720 acres (690 hectares) or about 2.7 square miles (7.0 km^2) of private property in the northwestern corner of Coyote Spring Valley (Drawing 4-1). The closest private lands outside the valleys are those near Moapa on the Muddy River (Pahranagat Wash).

There are three possible changes to the present land status which are awaiting future action. The first is the DNWR land withdrawal and wilderness applications filed in 1974. These applications would withdraw from the BLM a parcel of land between the DNWR on the west and U.S. Highway 93 on the east. This parcel could through the wilderness application, be added to the proposed wilderness land within the DNWR which would form a larger wilderness area. This same land, if withdrawn from BLM, would extend the present DNWR boundaries. This extension would form a buffer zone between the range activities and human contact. These applications, as filed by the U.S. Fish and

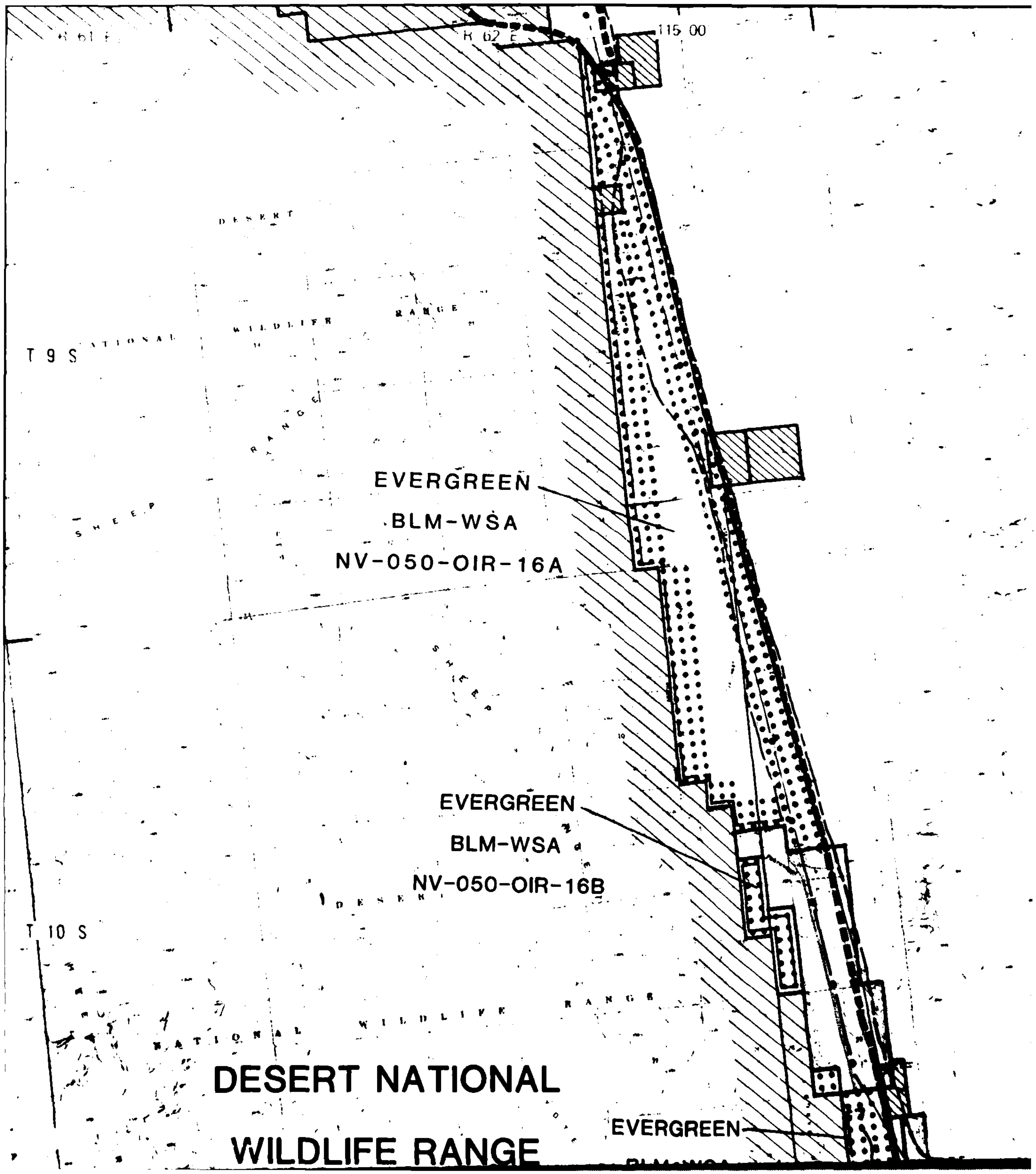
Wildlife Service, has had the effect of segregating the area so as to maintain its wilderness characteristics until such time as Congress acts on the application. Presently, the land withdrawal application is pending compliance with the Federal Land Management Organic Act, while the wilderness application is pending a mineral study of the area.

The second activity that has a potential for changing the present land status is an ongoing BLM Wilderness Inventory Study. This study is intended to examine areas which may have wilderness characteristics. During the BLM's initial wilderness inventory, several areas were identified for follow-on studies. Areas that will be field-checked during the next phase of the BLM study are:

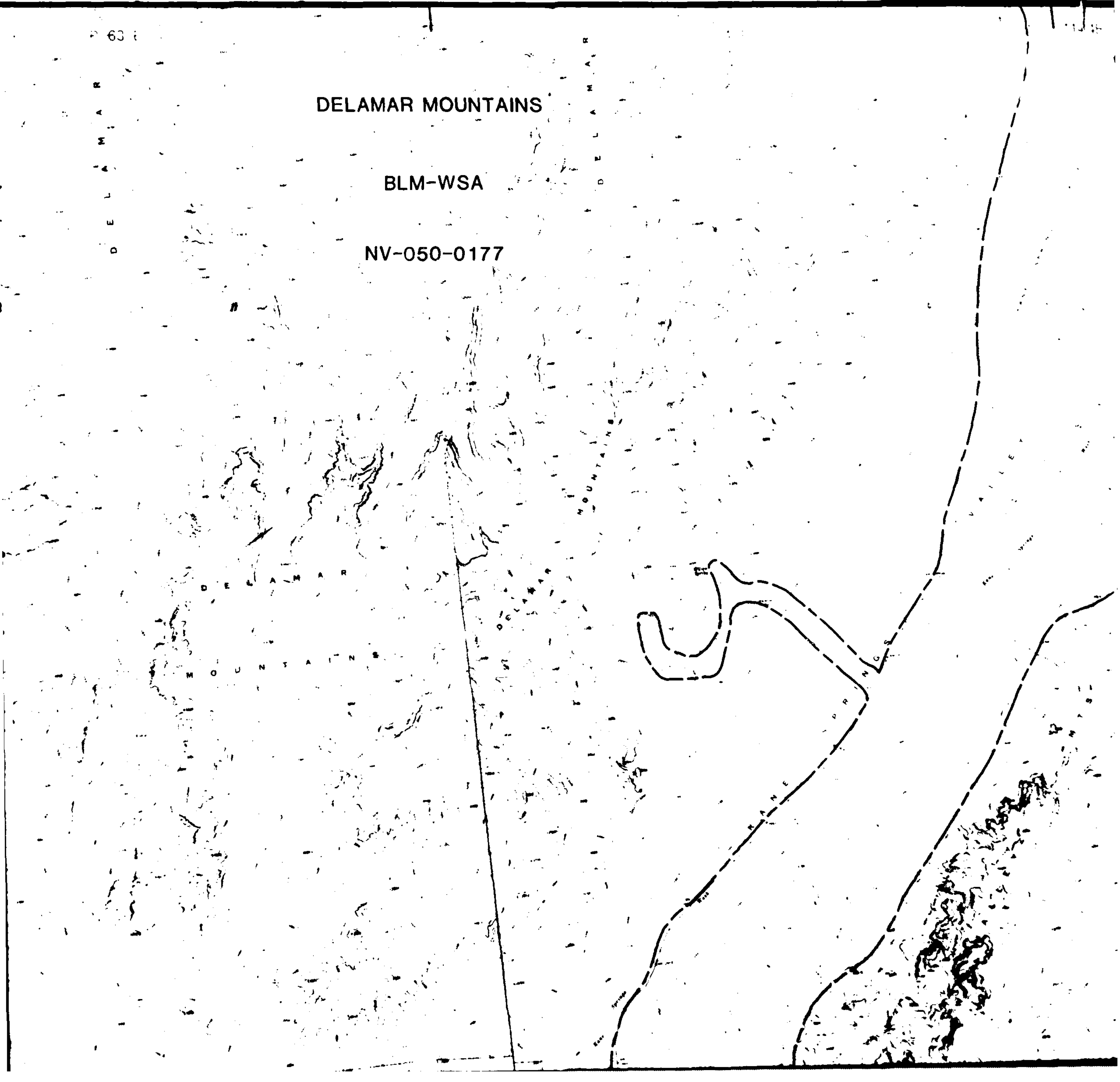
1. Delamar Mountains - north Coyote Spring/southern Kane Springs valleys;
2. Central Delamar Mountains - northern Kane Springs Valley;
3. Meadow Valley Range - southern Kane Springs/eastern Coyote Spring valleys;
4. Arrow Canyon Range - eastern Coyote Spring Valley; and
5. Fish and Wildlife Areas #1, #2, and #3 - western Coyote Spring Valley.

The last area listed above is the previously mentioned strip of land west of Highway 93.

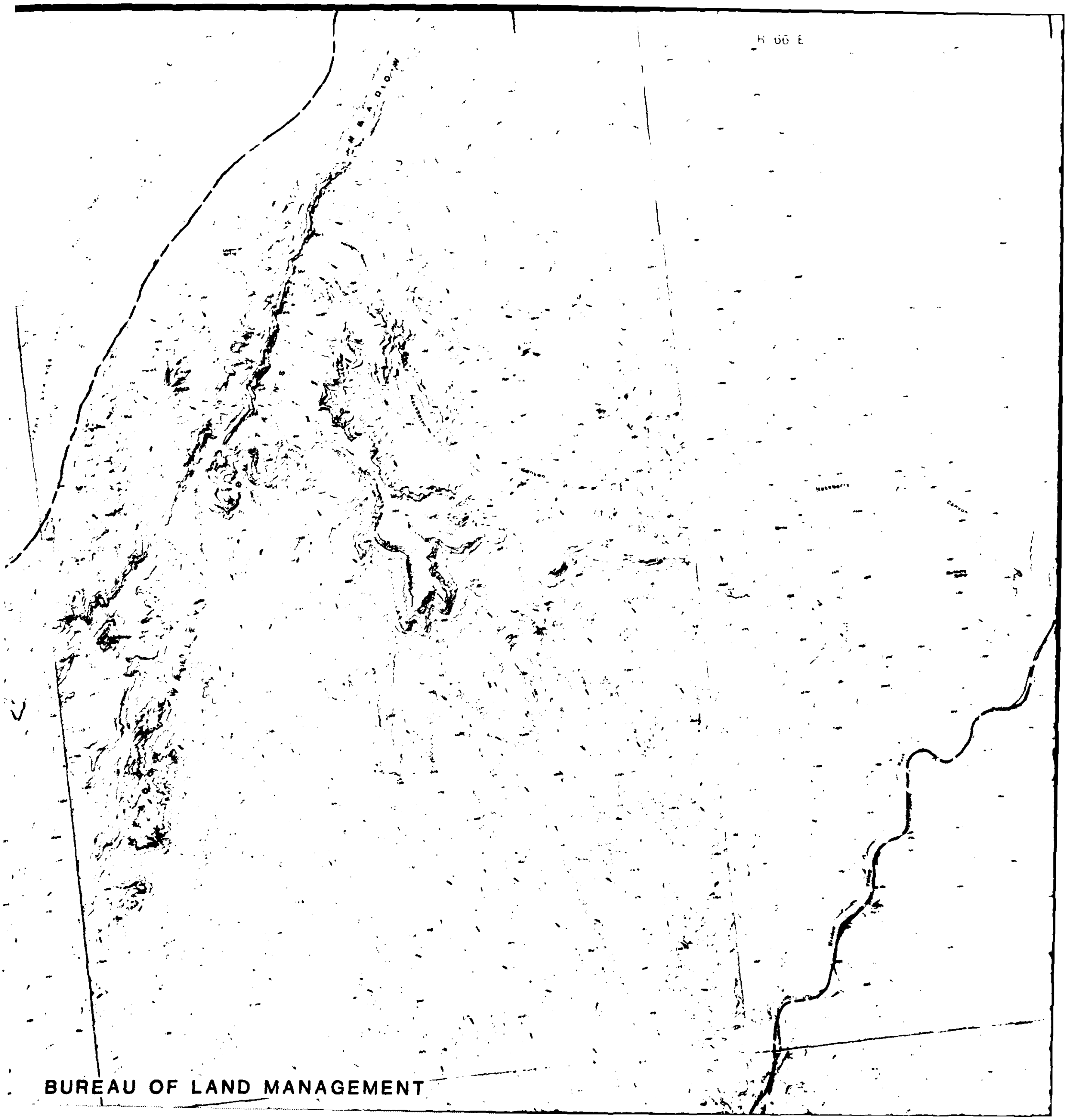
The third possible change in land status might result from a Desert Land Entry application (DLE) for 640 acres (260 hectares) in Pahranagat Wash, just north of State Route 7. Depending on the application's acceptance, this area could become private property.

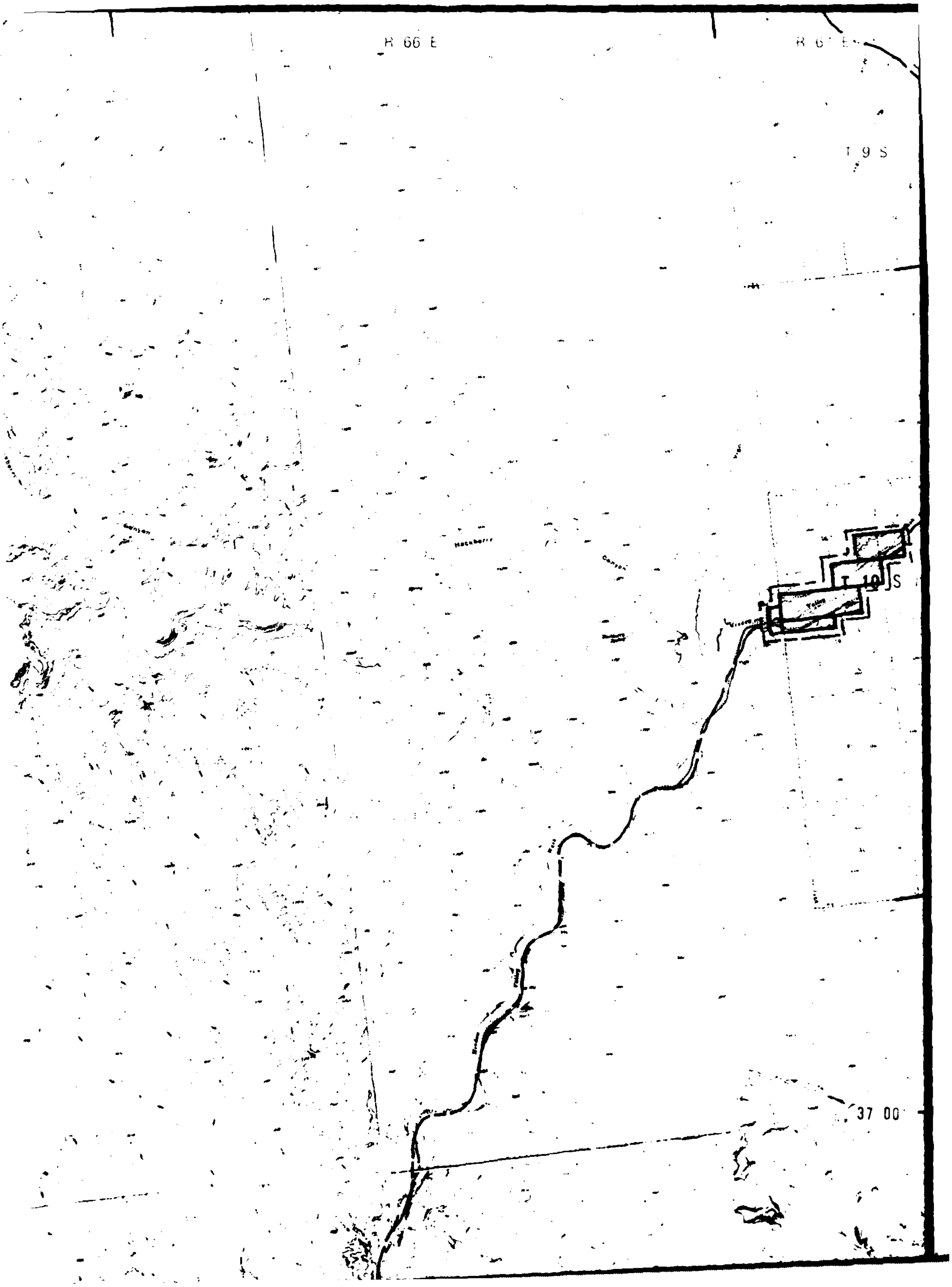

R 61 E
R 62 E
115 00
T 9 S
T 10 S
EVERGREEN
BLM-WSA
NV-050-OIR-16A
EVERGREEN
BLM-WSA
NV-050-OIR-16B
DESERT NATIONAL
WILDLIFE RANGE
EVERGREEN

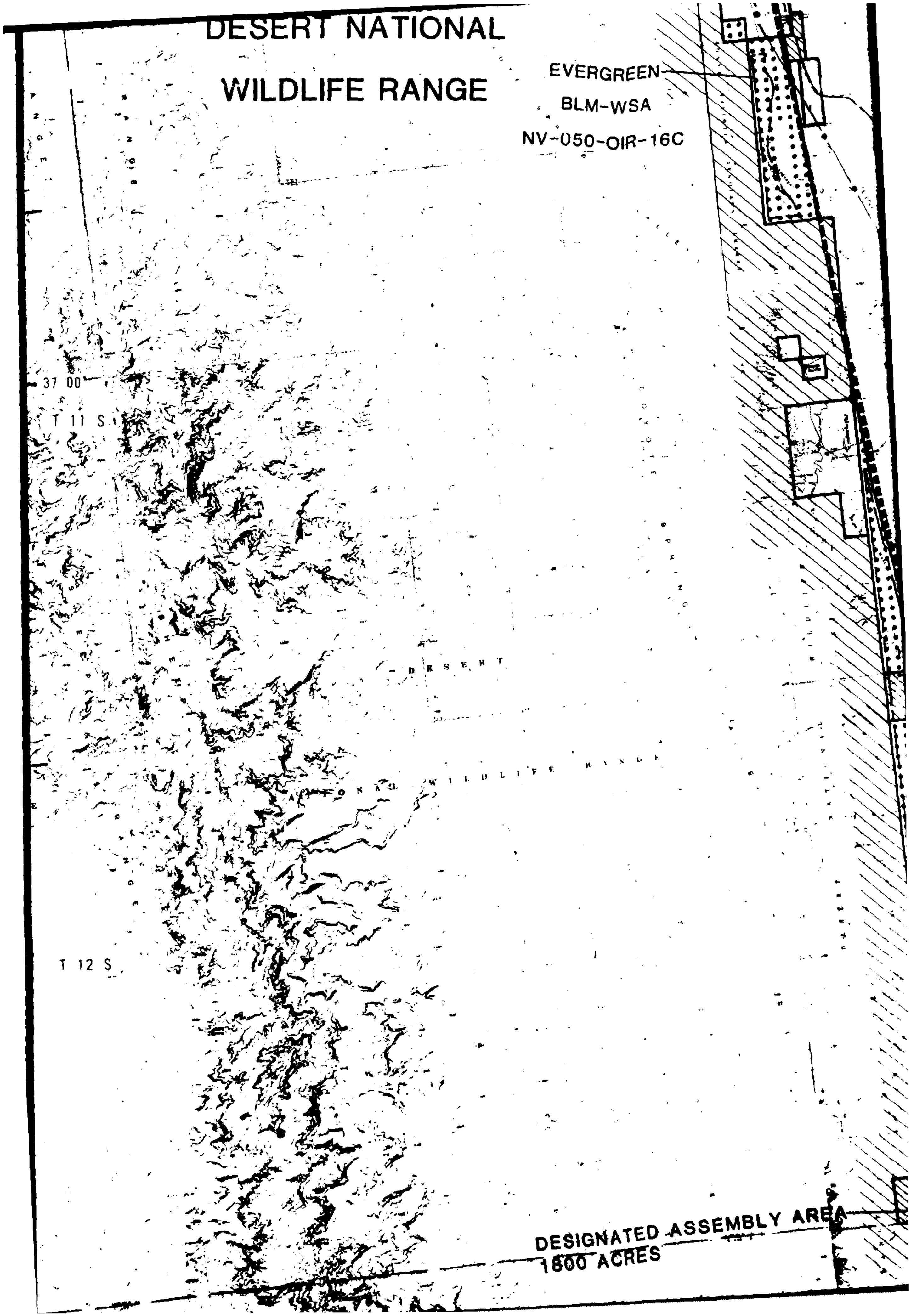
1 3



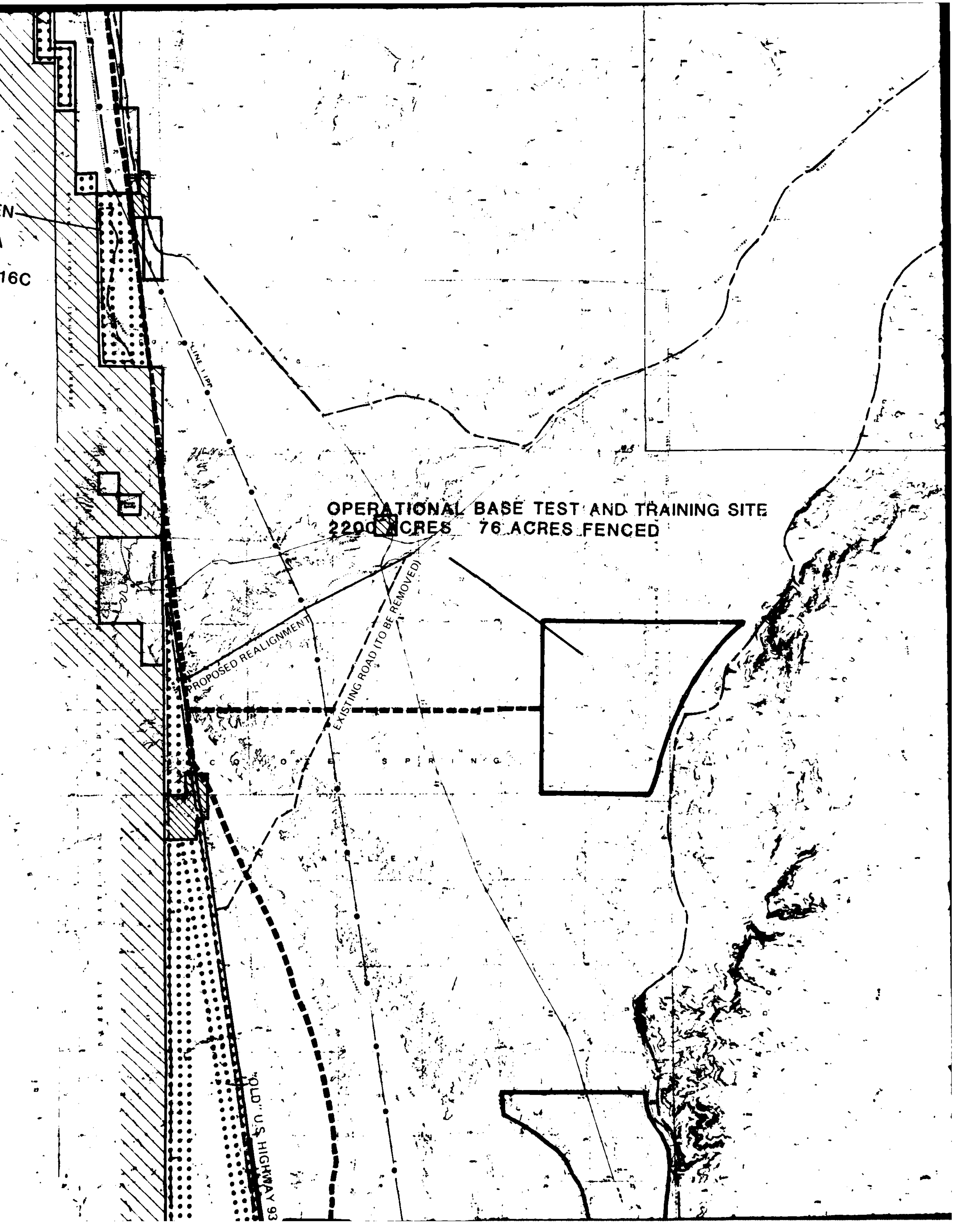
DELAMAR MOUNTAINS
BLM-WSA
NV-050-0177
DELAMAR
MOUNTAINS
DELAMAR
KANE SPRINGS


R 66 E
BUREAU OF LAND MANAGEMENT

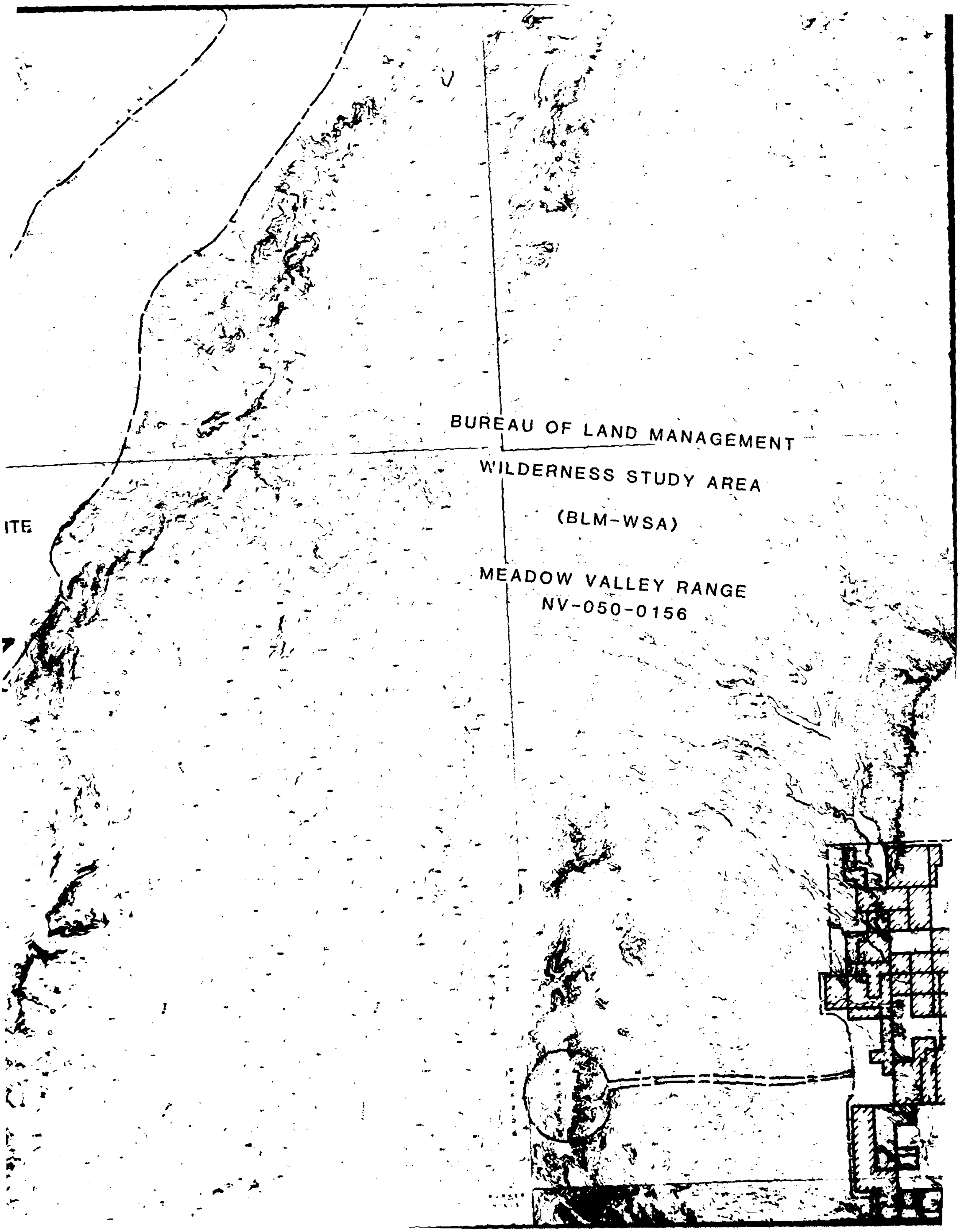

R 66 E
T 9 S
T 10 S
37 00'

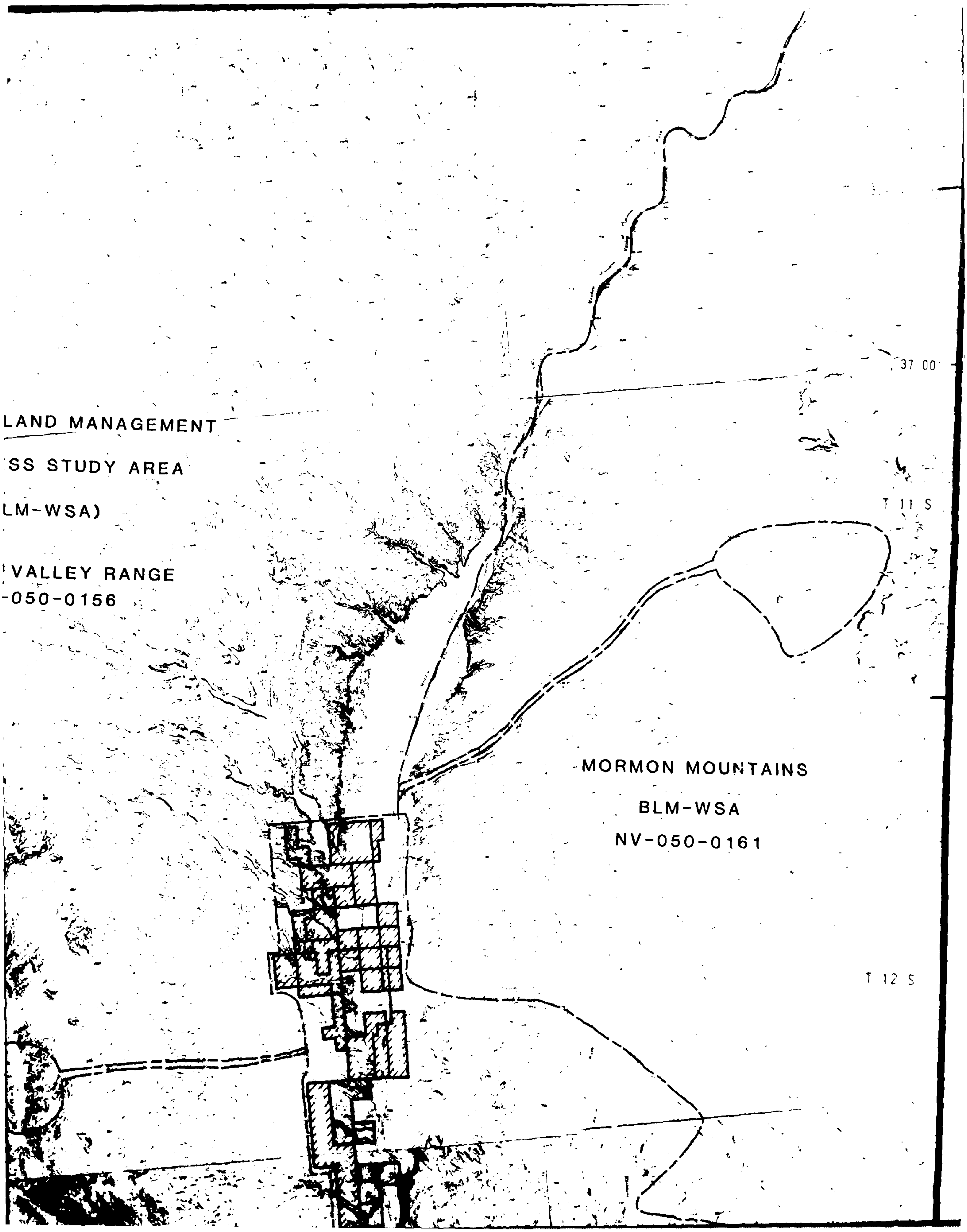


DESERT NATIONAL
WILDLIFE RANGE
EVERGREEN
BLM-WSA
NV-050-OIR-16C
37 00
T 11 S
T 12 S
DESIGNATED ASSEMBLY AREA
1800 ACRES

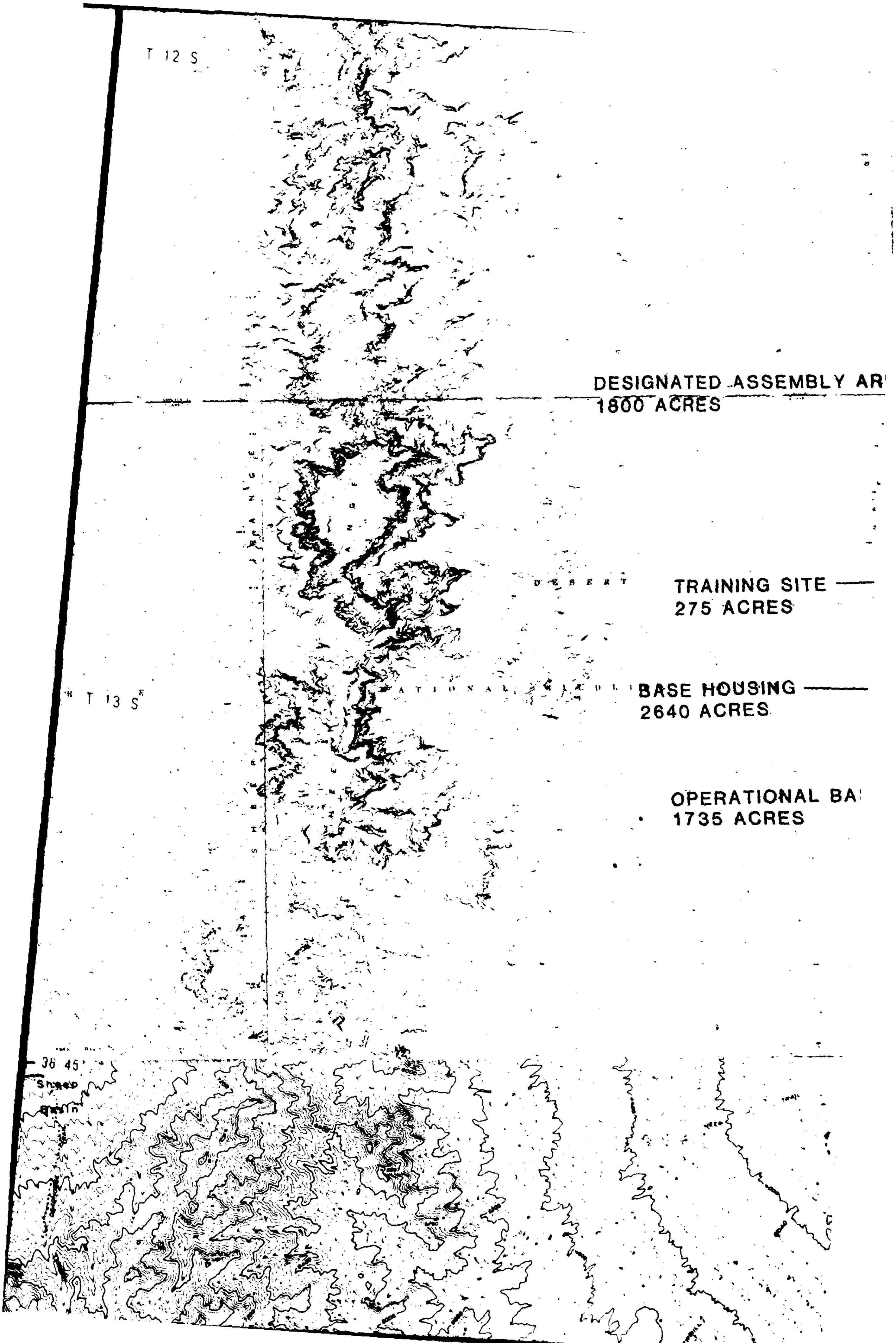


16C
OPERATIONAL BASE TEST AND TRAINING SITE
2200 ACRES 76 ACRES FENCED
LINE 1 IPP
PROPOSED REALIGNMENT
EXISTING ROAD (TO BE REMOVED)
C O Y O T E S P R I N G
V A L L E Y
"OLD" U.S HIGHWAY 93

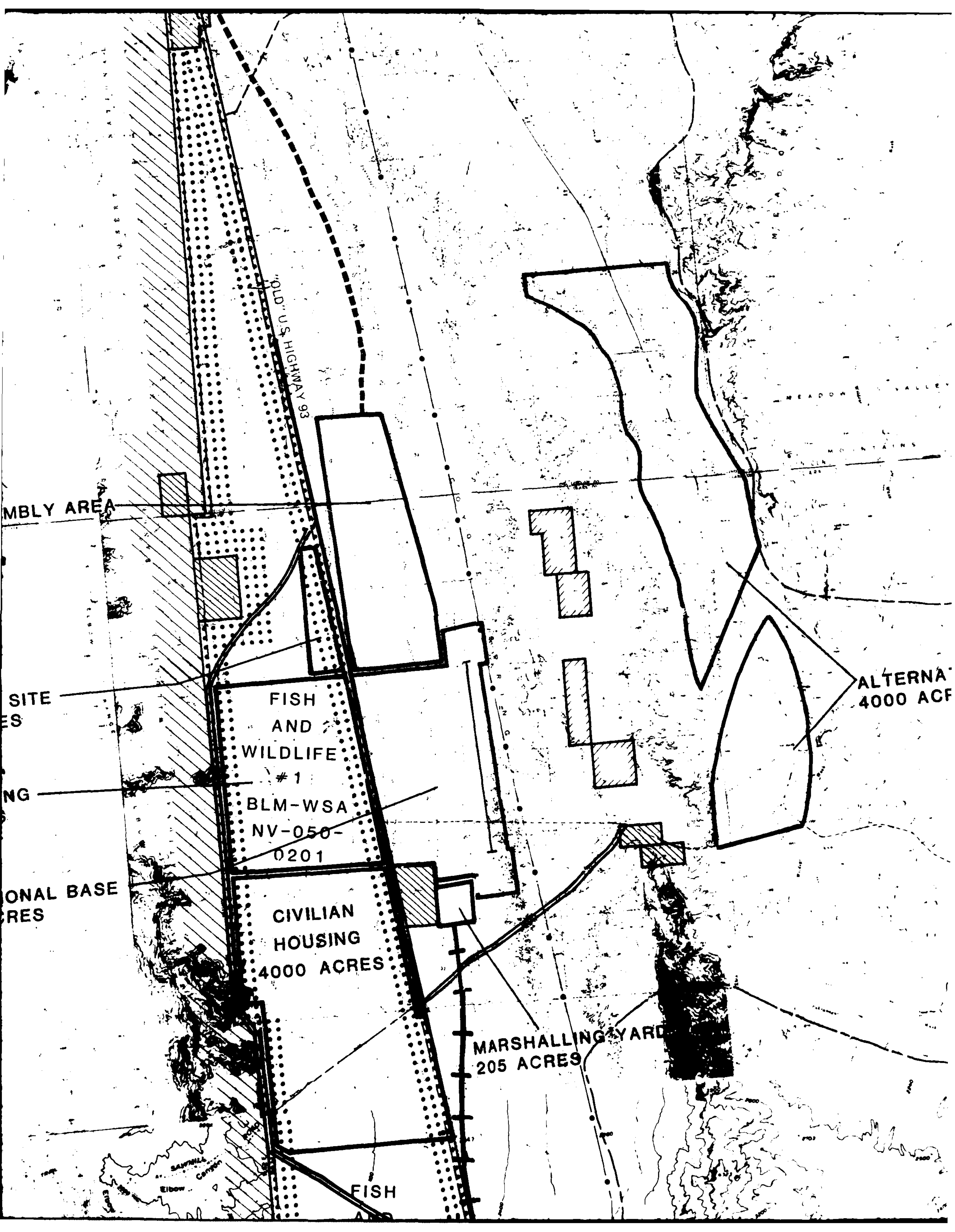

BUREAU OF LAND MANAGEMENT
WILDERNESS STUDY AREA
(BLM-WSA)
MEADOW VALLEY RANGE
NV-050-0156
ITE



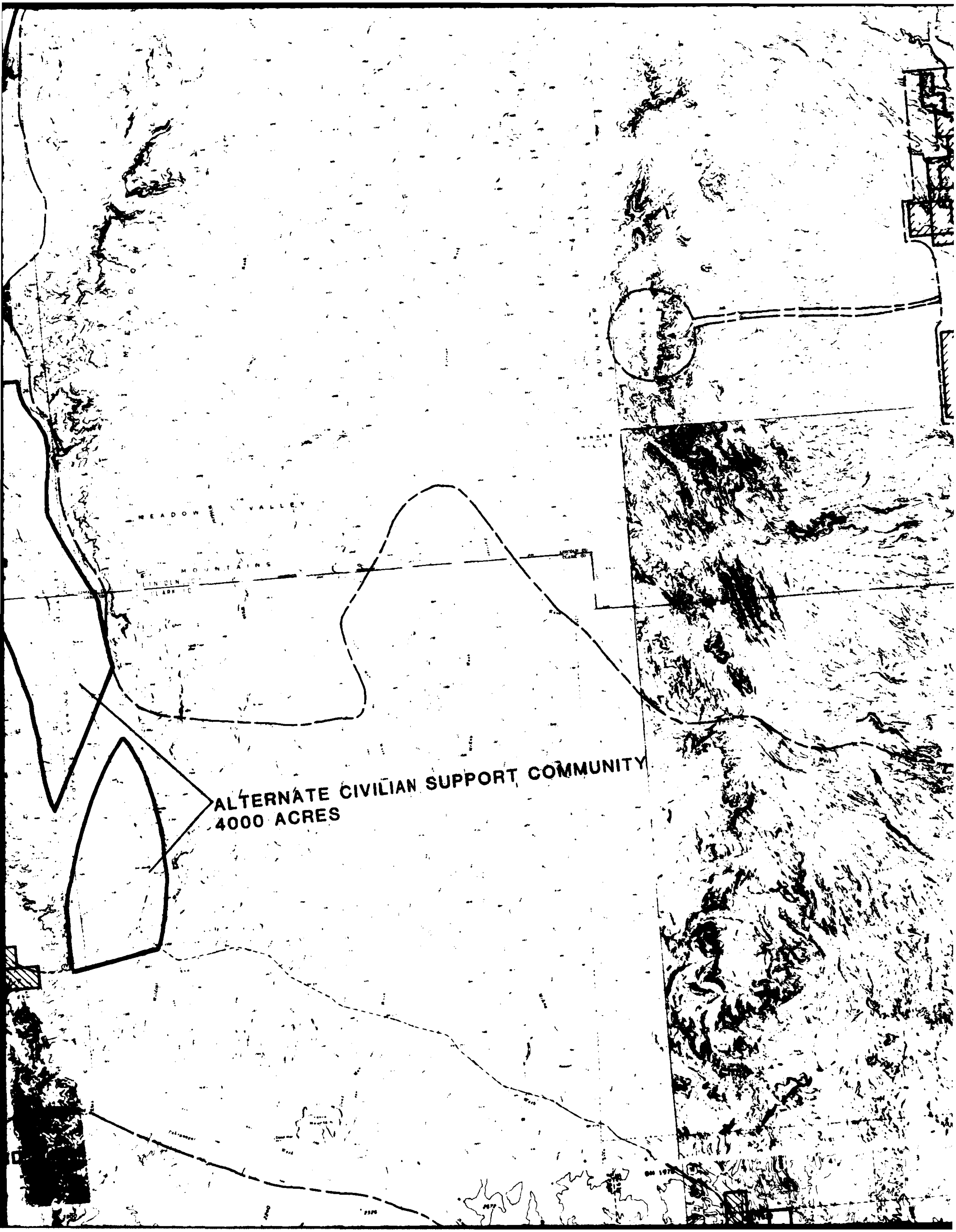
LAND MANAGEMENT
SS STUDY AREA
LM-WSA)
VALLEY RANGE
-050-0156
37 00'
T 11 S
MORMON MOUNTAINS
BLM-WSA
NV-050-0161
T 12 S

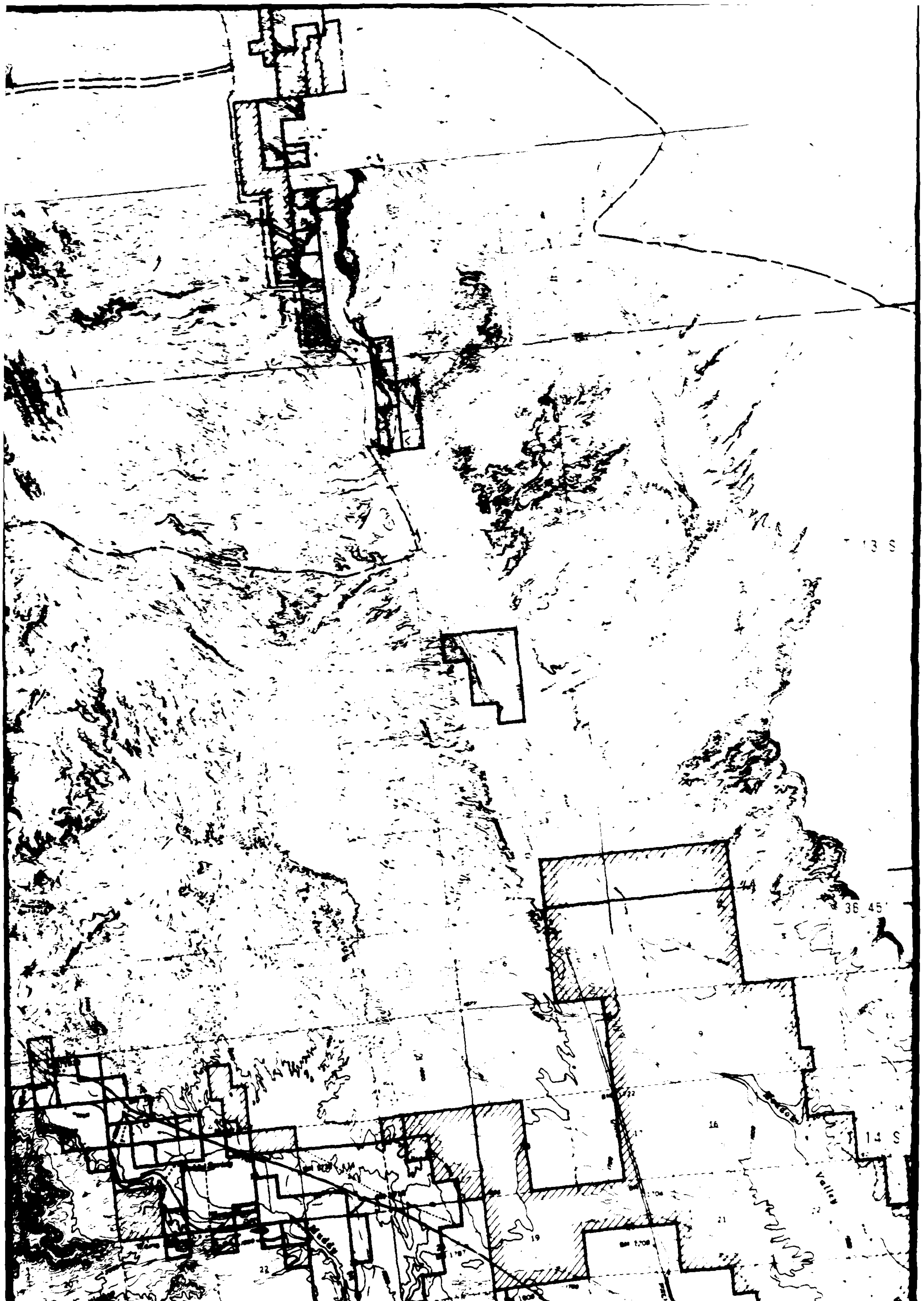


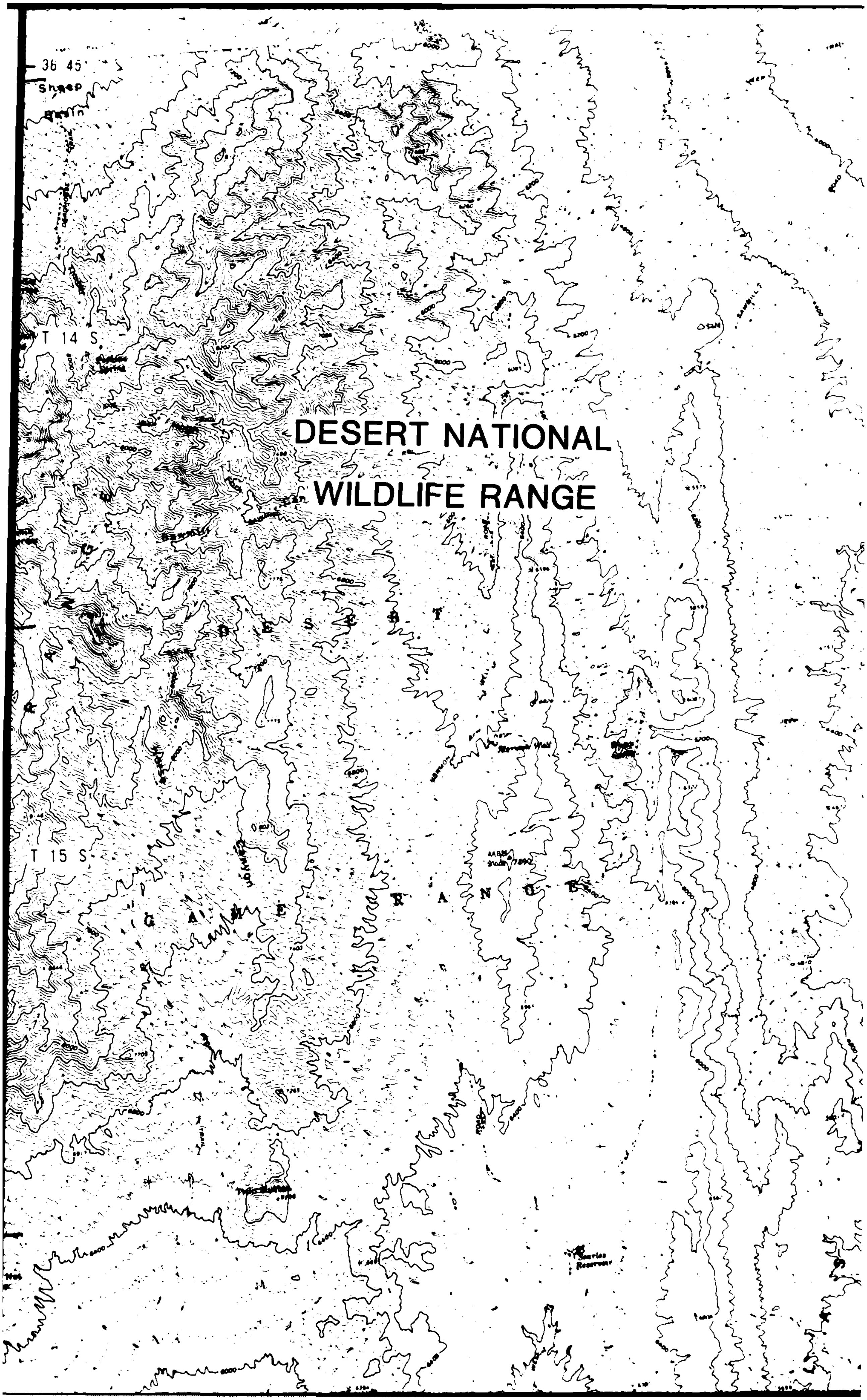
T 12 S
DESIGNATED ASSEMBLY AR
1800 ACRES
TRAINING SITE
275 ACRES
T 13 S
BASE HOUSING
2640 ACRES
OPERATIONAL BA
1735 ACRES
36 45
Sheep
Basin

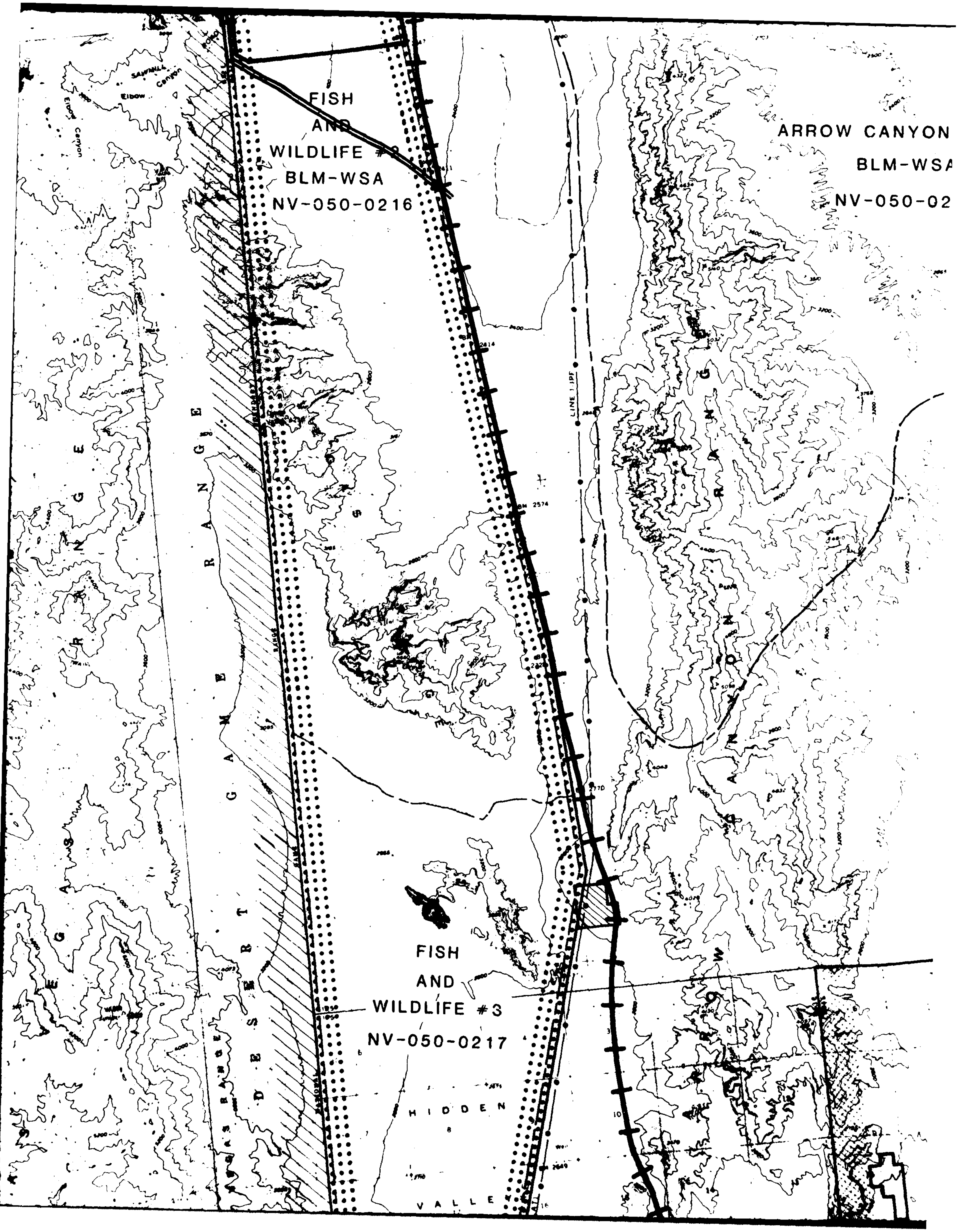


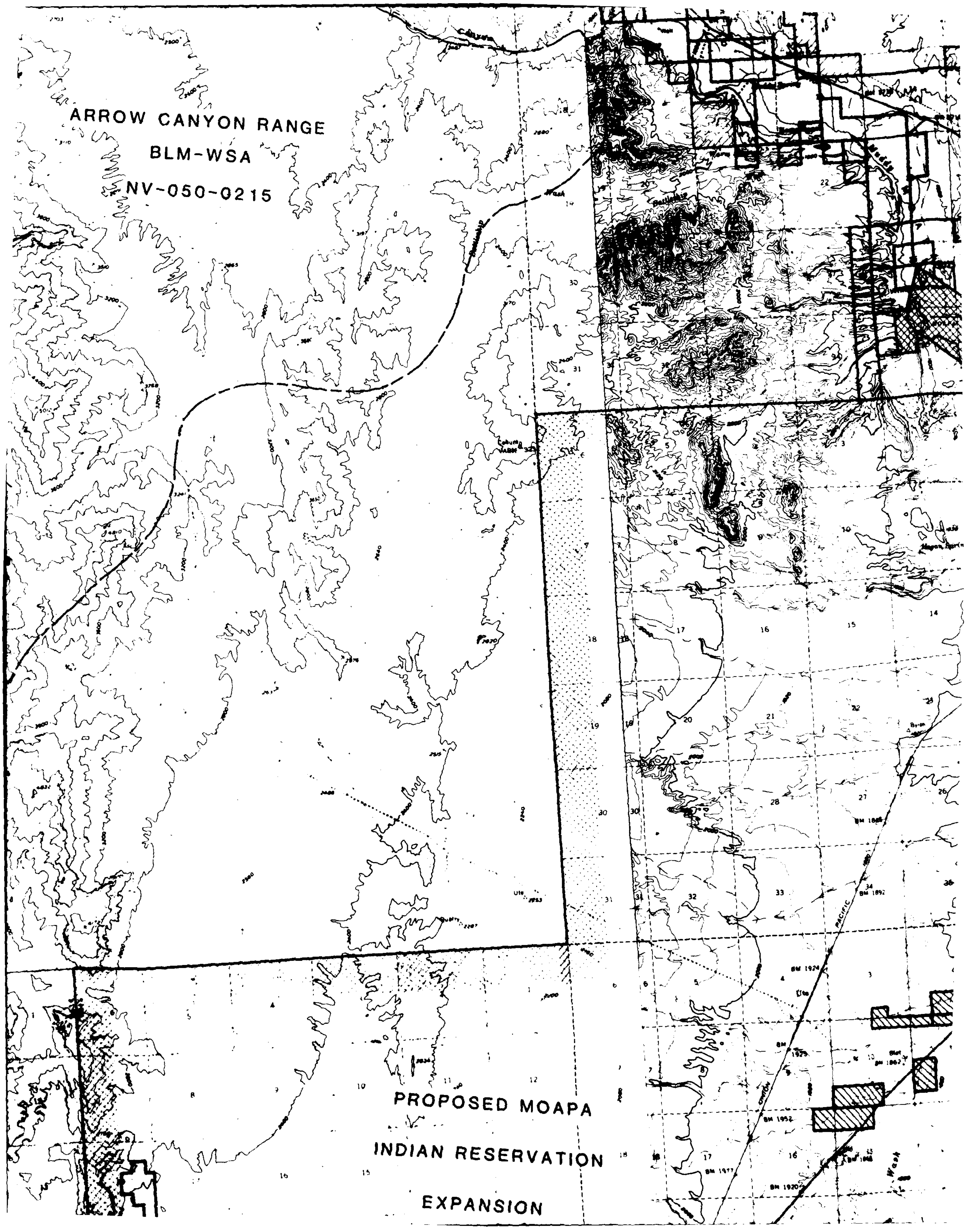
MBLY AREA
SITE
ES
NG
ONAL BASE
RES
"OLD" U.S. HIGHWAY 93
FISH
AND
WILDLIFE
#1
BLM-WSA
NV-050-
0201
CIVILIAN
HOUSING
4000 ACRES
MARSHALLING YARD
205 ACRES
ALTERNA
4000 ACF
MEADOW VALLEY
MOUNTAINS
FISH
AND

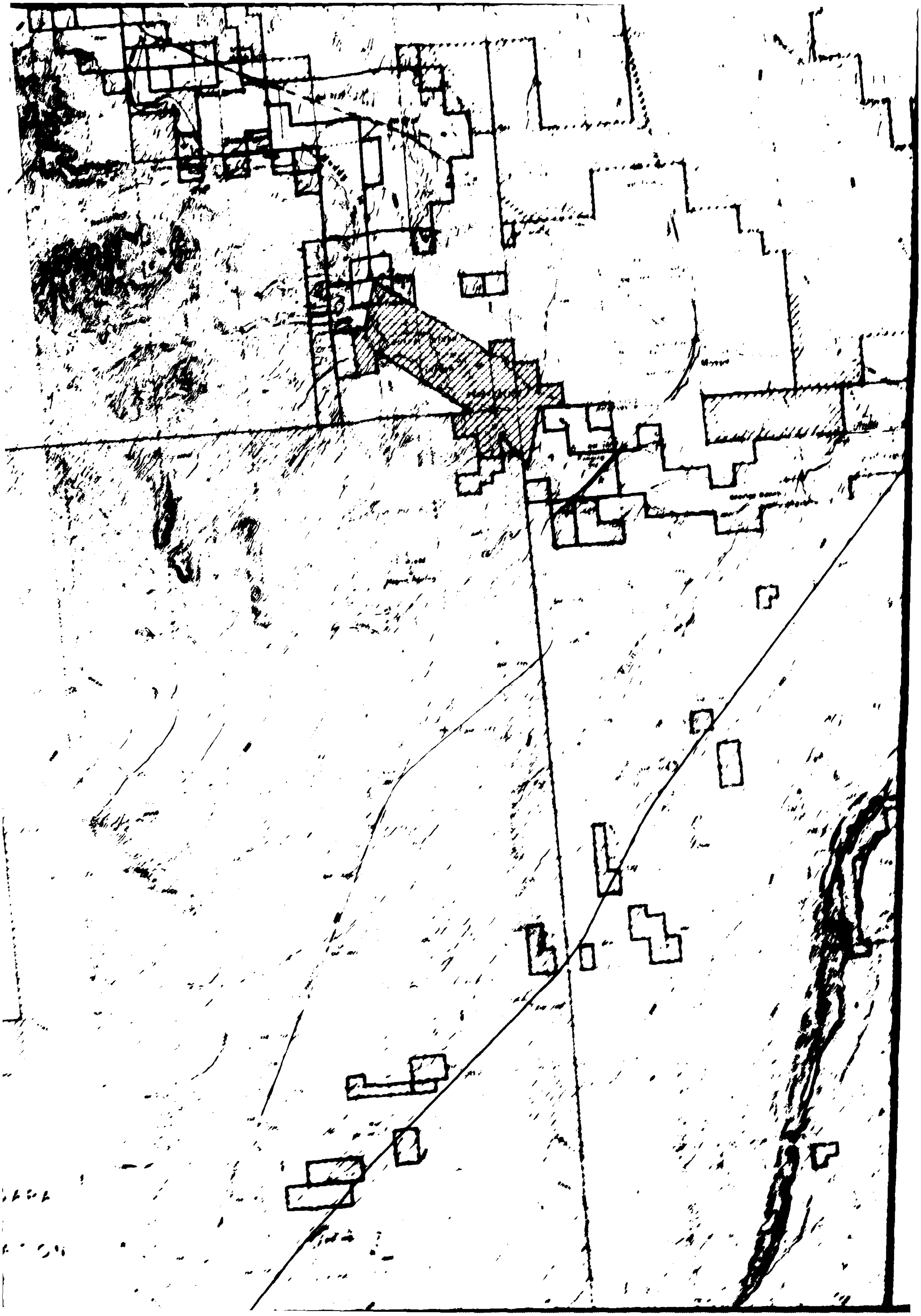

MEADOW VALLEY
MOUNTAINS
BUNKER HILLS
ALTERNATE CIVILIAN SUPPORT COMMUNITY
4000 ACRES

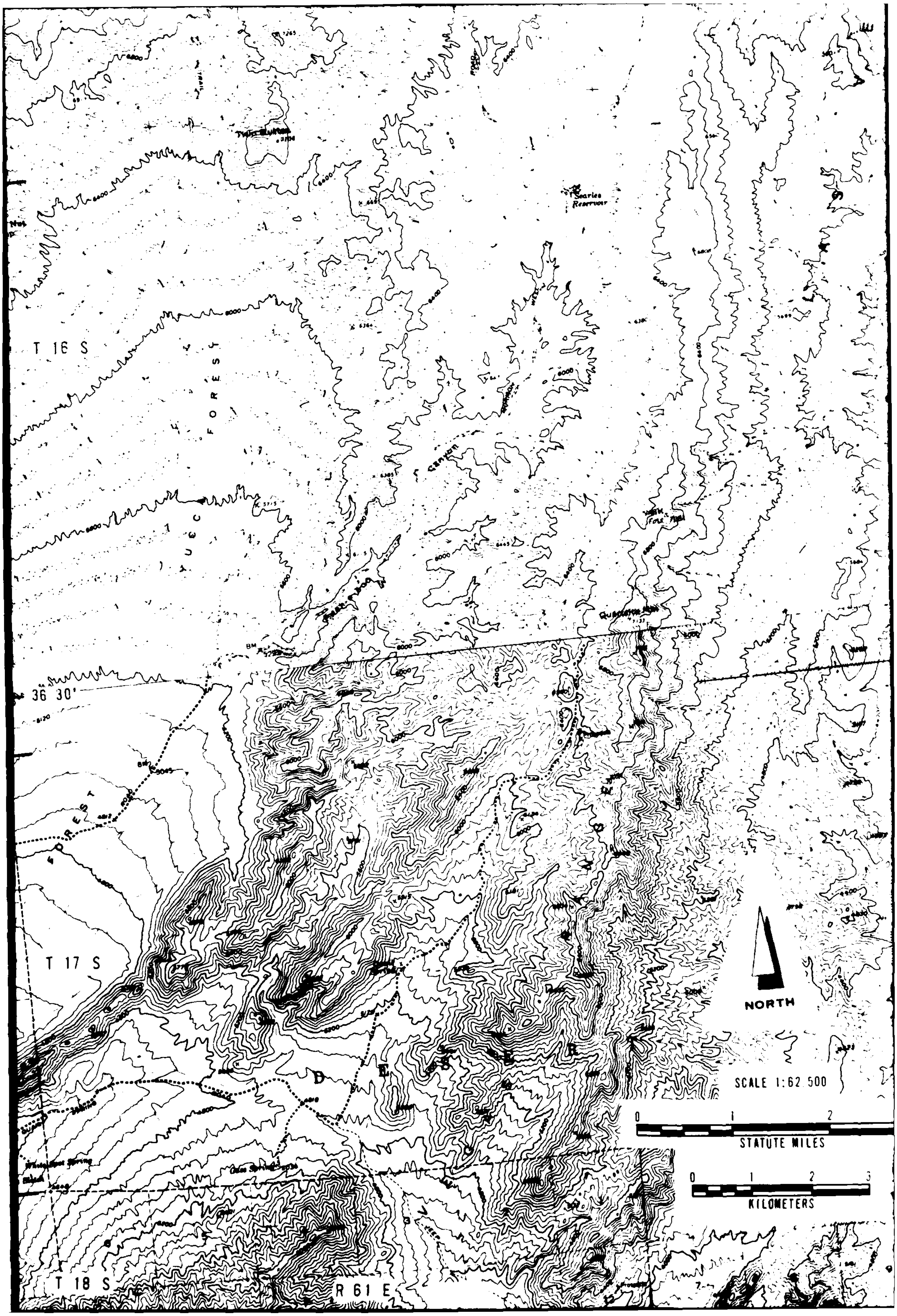

T 13 S
36 45'
T 14 S
Valley


36 45'
Sheep Basin
T 14 S
T 15 S
DESERT NATIONAL
WILDLIFE RANGE
D E S E R T
G A M E
R A N G E

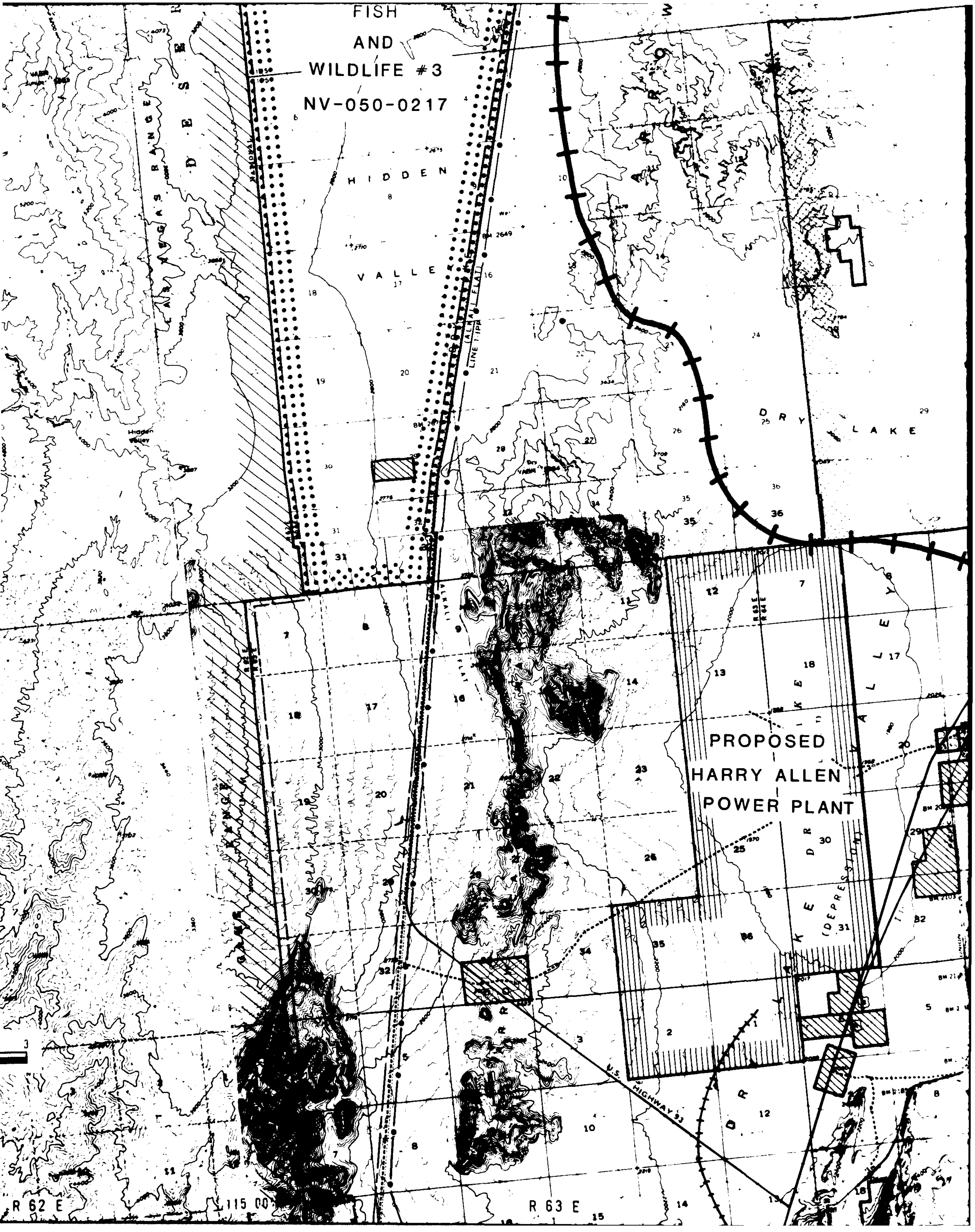

FISH
AND
WILDLIFE #2
BLM-WSA
NV-050-0216
ARROW CANYON
BLM-WSA
NV-050-02
DESERT RANGE
FISH
AND
WILDLIFE #3
NV-050-0217
HIDDEN
VALLE


ARROW CANYON RANGE
BLM-WSA
NV-050-0215
PROPOSED MOAPA
INDIAN RESERVATION
EXPANSION

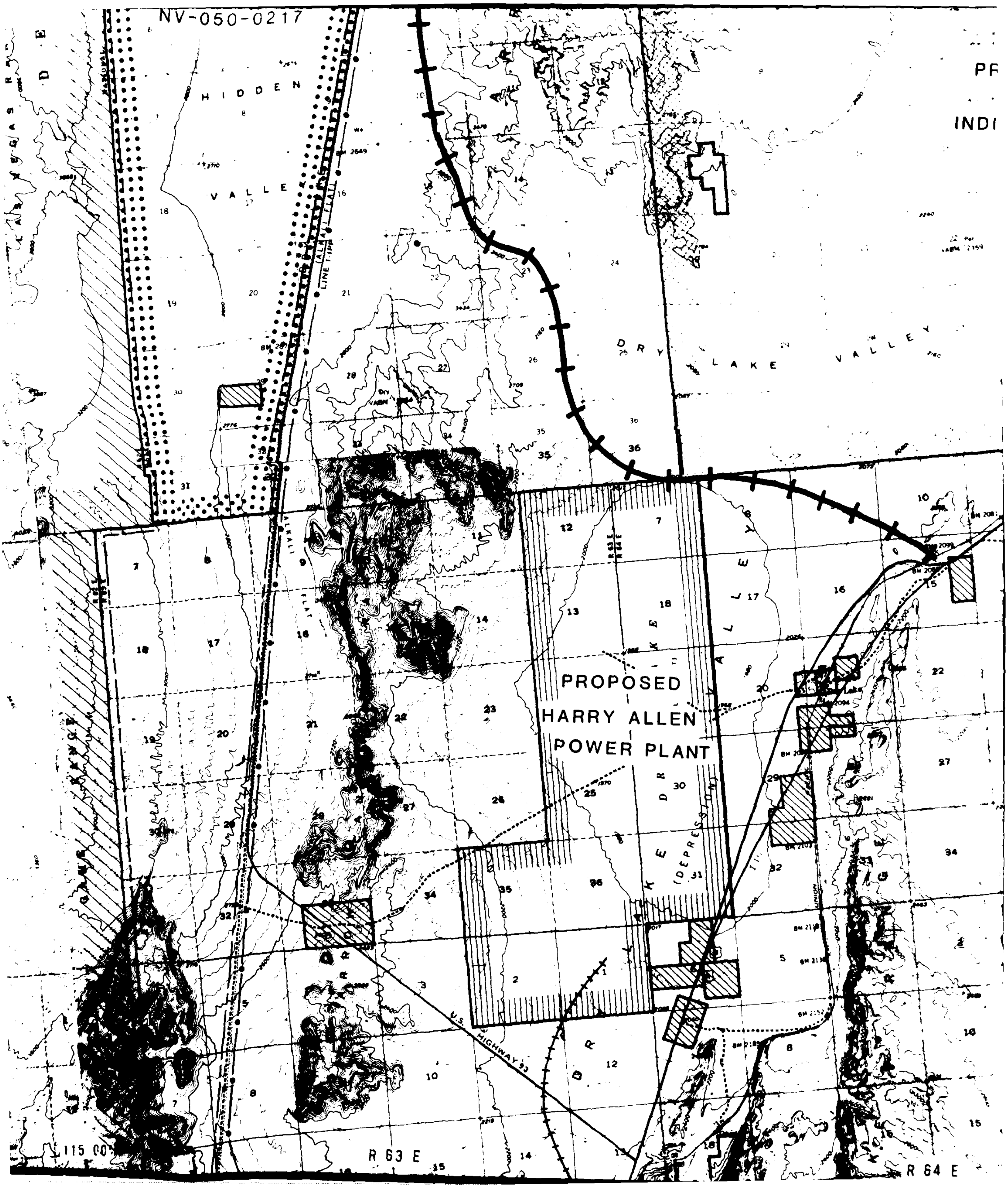




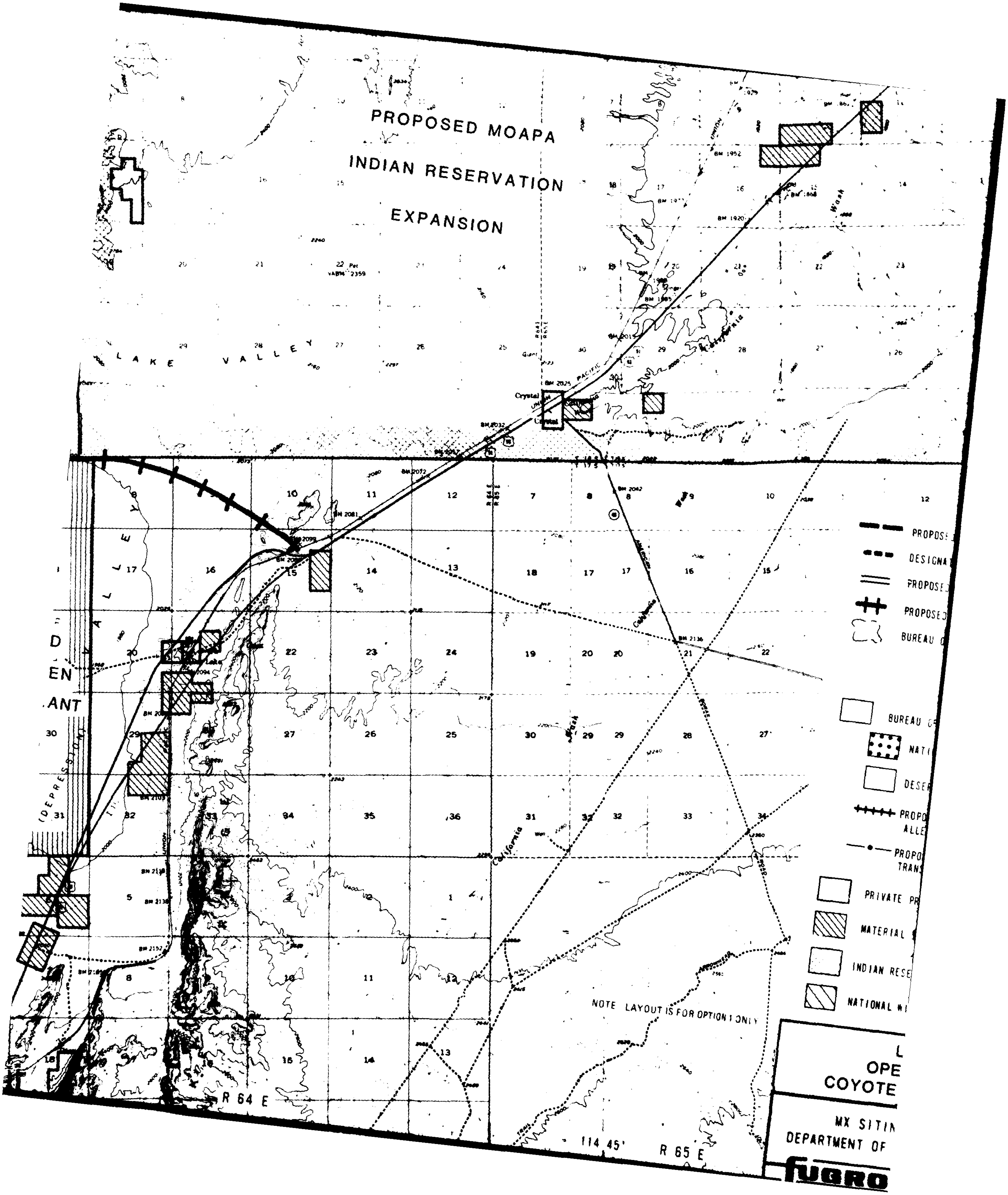
T 16 S
T 17 S
T 18 S
R 61 E
36 30'
Searles Reservoir
NORTH
SCALE 1:62 500
0 1 2
STATUTE MILES
0 1 2 3
KILOMETERS



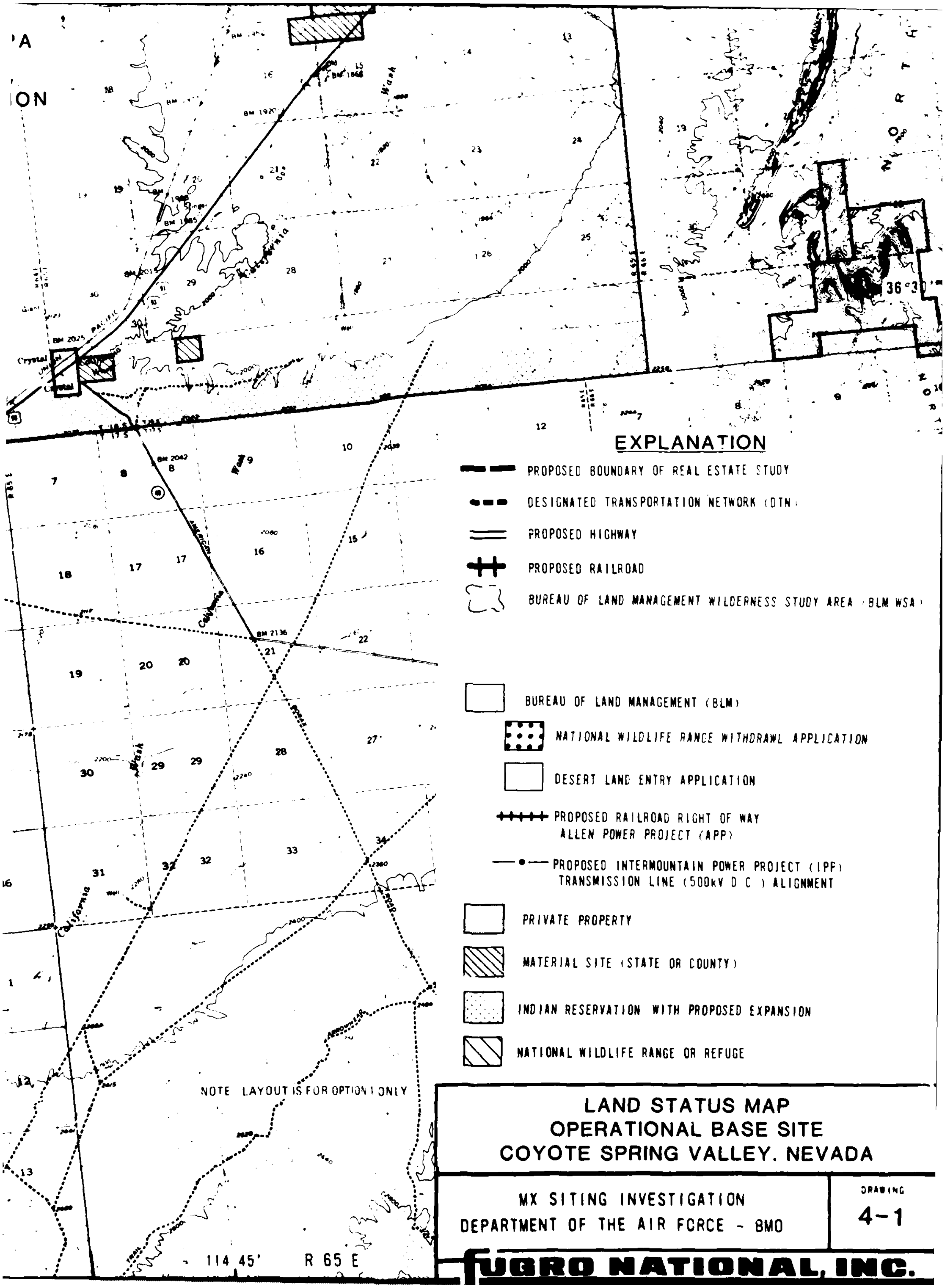
FISH
AND
WILDLIFE #3
NV-050-0217
HIDDEN
VALLE
DRY LAKE
PROPOSED
HARRY ALLEN
POWER PLANT
DRY LAKE VALLEY
(DEPRESSION)
U.S. HIGHWAY 93
R 62 E
115 00
R 63 E



NV-050-0217
HIDDEN VALLEY
DRY LAKE VALLEY
PROPOSED
HARRY ALLEN
POWER PLANT
U.S. HIGHWAY 93
DRY LAKE (DEPRESSION)
ALKALI FLAT
R 63 E
R 64 E
INDI



PROPOSED MOAPA
INDIAN RESERVATION
EXPANSION
LAKE VALLEY
UNION PACIFIC
Crystal
California Wash
(DEPRESSION)
PROPOSE
DESIGNA
PROPOSE
PROPOSE
BUREAU O
BUREAU O
NATI
DESER
PROPO ALLE
PROPO TRANS
PRIVATE PR
MATERIAL
INDIAN RESE
NATIONAL W
NOTE LAYOUT IS FOR OPTION 1 ONLY
L
OPE
COYOTE
MX SITIN
DEPARTMENT OF
FUGRO
R 64 E
114 45'
R 65 E


EXPLANATION
PROPOSED BOUNDARY OF REAL ESTATE STUDY
DESIGNATED TRANSPORTATION NETWORK (DTN)
PROPOSED HIGHWAY
PROPOSED RAILROAD
BUREAU OF LAND MANAGEMENT WILDERNESS STUDY AREA (BLM WSA)
BUREAU OF LAND MANAGEMENT (BLM)
NATIONAL WILDLIFE RANGE WITHDRAWL APPLICATION
DESERT LAND ENTRY APPLICATION
PROPOSED RAILROAD RIGHT OF WAY
ALLEN POWER PROJECT (APP)
PROPOSED INTERMOUNTAIN POWER PROJECT (IPP)
TRANSMISSION LINE (500kV D C) ALIGNMENT
PRIVATE PROPERTY
MATERIAL SITE (STATE OR COUNTY)
INDIAN RESERVATION WITH PROPOSED EXPANSION
NATIONAL WILDLIFE RANGE OR REFUGE
NOTE LAYOUT IS FOR OPTION 1 ONLY
Crystal
Wash
California
36°3
114 45'
R 65 E
LAND STATUS MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO
DRAWING
4-1
FUGRO NATIONAL, INC.

5.0 GEOTECHNICAL CONDITIONS

5.1 REGIONAL GEOLOGIC SETTING

The proposed OB site lies within the Great Basin portion of the Basin and Range physiographic province. The Great Basin, which includes most of Nevada and portions of adjacent states, is characterized by north-south trending mountains separated by broad desert valleys which generally contain thick accumulations of sediments (basin-fill deposits). Most of the valleys are closed basins with no drainage to the sea. Relief between valleys and adjoining mountains is generally less than 5000 feet (1524 m). Many of the mountain fronts are linear because they were formed, and are still being formed, by faulting. Most of the "typical" Basin and Range topography began forming in the late Tertiary period (about 10 million years ago).

5.2 SITE GEOLOGIC UNITS

Most of the proposed OB site area is underlain by late Cenozoic sedimentary units ranging from late Pliocene lake sediments to recent unconsolidated alluvial fan and stream channel deposits which overlie most of the Pliocene sediments. Drawing 5-1 shows the surficial distribution of the units. A brief description of each unit is provided in the following sections.

5.2.1 Pre-Cenozoic Bedrock (PCz)

The mountain ranges bordering the site area are composed primarily of pre-Cenozoic limestone and dolomite with minor amounts of quartzite and shale. In the southernmost Delamar Mountains (immediately northwest of Kane Springs Wash) and in the Meadow Valley Mountains (east of Coyote Spring Valley) isolated outcrops of Tertiary volcanic rock unconformably overlie the pre-Cenozoic rocks. The limestone and dolomite are generally gray and dark gray, thick-bedded to massive, and are commonly jointed. Bedding is defined by differential erosion and minor partings between beds. Small joints are usually discontinuous and spaced a few inches to several feet apart. Very large, near vertical joints or "cracks," subparallel to the mountain front, were observed in the bedrock east of the proposed OBTS. Some of these cracks appeared to be several feet wide and several hundred feet long.

The bedding in the pre-Cenozoic bedrock bordering the site area generally strikes northerly and dips to the east. Local variations to this regional trend are common due to belts of strong folding and complex structures. The pre-Cenozoic rocks are cut by numerous approximately east-west, northwest, and north-south striking faults, including strike slip and thrust faults.

An isolated outcrop of limestone and dolomite occurs about 1 1/2 miles (2.4 km) north of State Route 7 on the western side of Pahranagat Wash (Drawing 5-1). It has the same general characteristics as the bedrock in the ranges bordering the site area as described above.

5.2.2 Tertiary Lake Sediments (Tys)

Late Tertiary lake (lacustrine) sediments of probable Pliocene age are exposed mainly in the central and southeastern portions of the site area. Exposures consist dominantly of interbedded mudstone, siltstone, sandstone, pebbly sandstone, conglomerate, freshwater limestone and water-laid tuff. The mudstone and siltstone compose about 70 percent of the exposed lake sediments. The sandstone, conglomerate, limestone and tuff compose the remaining 30 percent. Most of the lake deposits are exposed in steep walls of incisions and bluffs. Bedding attitudes (dip and strike) are variable with dips ranging from less than one degree to a maximum of about 25 degrees, and generally averaging less than 5 degrees either westerly or easterly.

The major soil types within the Tertiary lake sediments are briefly described below.

- Mudstone and Siltstone - The mudstone-siltstone exposures vary in color from red-brown to green-gray to gray and gray-brown and generally consist of laminated beds commonly greater than 10 feet (3 m) thick. Unweathered mudstone and siltstone beds are indurated and have the characteristics of a hard soil. Exposures are generally moderately weathered and coated with fairly soft weathered silty clay deposits that vary from a few inches to greater than a foot thick. The surfaces of these deposits consist of a pervasively cracked crust less than 1/8-inch (0.3 cm) thick. Gypsum crystals were observed in some of the mudstone exposures.

- Sandstone and Pebbly Sandstone - Sandstone and pebbly sandstone beds occur as relatively resistant, slightly to moderately weathered light-gray and gray-brown outcrops. They are commonly dense and moderately cemented. Many of the sandstone beds can be traced laterally for several hundred feet and appear very tabular. The beds vary from less than a foot thick to several feet thick. Individual sandstone beds are generally laminated to thin bedded and are sometimes cross bedded.

- Conglomerate - The conglomerate exposures are gray and gray-brown, medium dense to very dense, and moderately well cemented. They are generally poorly bedded, and individual conglomerate layers cannot be traced laterally for more than a few tens of feet. Conglomerate sequences generally do not exceed 5 feet (1.5 m) in thickness. Clasts within the conglomerates consist predominantly of slightly weathered light colored subrounded pebble- and cobble-size volcanic rock fragments.

- Freshwater Limestone - The only exposures of freshwater limestone that were observed within the area mapped are in the walls of a canyon (Wildcat Wash) just north of the intersection of State Highway 7 and "old" U.S. 93. The limestone is pinkish-brown to greenish-brown, well bedded, and overlying a lens of cemented conglomerate. The freshwater limestone is generally very hard.

With regard to the following discussions, the Tertiary lake sediments are not regarded as "rock" because they have seismic velocities of less than 7000 feet per second (2134 mps) and are generally rippable.

5.2.3 Intermediate (A5i) and Older (A5o) Age Alluvial Fan Deposits

Intermediate and older age alluvial fan deposits are described together because they both have the same physical characteristics and appear very similar in exposures. They have been mapped separately on the basis of their morphology, and, in part, on their relative stratigraphic positions.

Intermediate and older age alluvial fan deposits compose about 20 percent and 30 percent of the area mapped, respectively. The A5i and A5o deposits consist predominantly of poorly to moderately well-graded, subangular to subrounded limestone and dolomitic gravels. They are dense to very dense and cemented to varying degrees by calcium carbonate. The detritus of these fan deposits appears to have been locally derived from the mountain ranges bounding the site area and reflects the lithology of these ranges. The limestone and dolomite clasts are slightly weathered and are generally very hard. Most of the gravels are clast supported. The matrix generally consists of variable amounts of sand, silt and clay.

Bedding is poorly developed and is usually defined by clast size changes. In general, it appears that the gravel deposits are very lenticular and individual beds lens out over relatively short distances. Sand and pebbly sand lenses occur in some of the outcrops. Resistant, calcium carbonate cemented gravel beds that vary from about 3 to 8 feet (0.9 to 2.4 m) thick locally crop out in some areas where they conspicuously protrude from incision walls. Some can be traced continuously for several hundred feet. These beds are shown on the geologic map (Drawing 5-1) as resistant gravel beds. Most of the A5i and A5o surfaces are covered with poor to moderately developed desert pavement consisting predominantly of limestone pebbles and cobbles.

Although attitudes (strike and dip) are variable, the gravels appear to dip gently (7 degrees) and become thinner toward the valley axis.

5.2.4 <u>Young Alluvial Fan Deposits (A5y)</u>

About 30 percent of the area mapped is covered with young alluvial fan deposits composed predominantly of limestone gravels. The young fans generally consist of two basic elements: stream channels (commonly braided) and abandoned areas of former fan surfaces. The channels are commonly shallow (generally less than 3 feet [0.9 m] deep) and contain loose to medium dense deposits of poorly to moderately well graded subangular to subrounded gravel and sand. In addition, many of the channels contain linear concentrations of subangular cobbles and boulders. The cobbles and boulders are essentially unweathered and are very hard. The channels vary in width from a few feet to several tens of feet. The abandoned areas between channels are generally covered with incipient desert pavement consisting of limestone pebbles and cobbles with scattered boulders and cobbles protruding above the surface. The near-surface gravels in the channel divides appear to be slightly cemented with calcium carbonate. Most of the exposures in shallow channel walls can be ravelled. However, exposures in some of the deeper incisions indicate that the degree of cementation probably increases with depth. Caliche layers are probably present within some of the A5y units.

Small well formed young alluvial fans occur along the margins of Pahranagat and Kane Springs washes where alluvial channels enter these washes.

5.2.5 Young Fluvial Deposits (A1)

Young fluvial deposits consist of recent stream channel and floodplain deposits such as those in Kane Springs and Pahranagat washes. The near surface deposits consist dominantly of uncemented sand, silty sand and gravel (very loose consistency). The gravels generally consist of subangular pebbles and cobbles of limestone, dolomite, and silicic volcanic rocks. The clasts are largely unweathered and are very hard.

Generally, 3 to 5 feet (0.9 to 1.5 m) below the surface, the deposits become slightly indurated and, on the whole, are loose to medium dense. The deposits are commonly lenticular and vary in composition and consistency laterally and vertically.

5.3 SUBSURFACE CONDITIONS

5.3.1 Thickness of the Geologic Units

Regional considerations and observations during the geologic mapping indicate that the thicknesses of the sediments are as follows:

- Tertiary Lake Sediments (Tys) - Basin-fill deposits several thousand feet thick are common in the Great Basin. The lake sediments in the site area are probably much thicker than the few hundred feet currently exposed in Coyote Spring Valley. A recent hydrologic well drilled immediately west of U.S. Highway 93 about one and a half miles (2.4 km) north of the Lincoln Clark County line indicates that the Tertiary lake sediments are greater than 750 feet (229 m) thick.

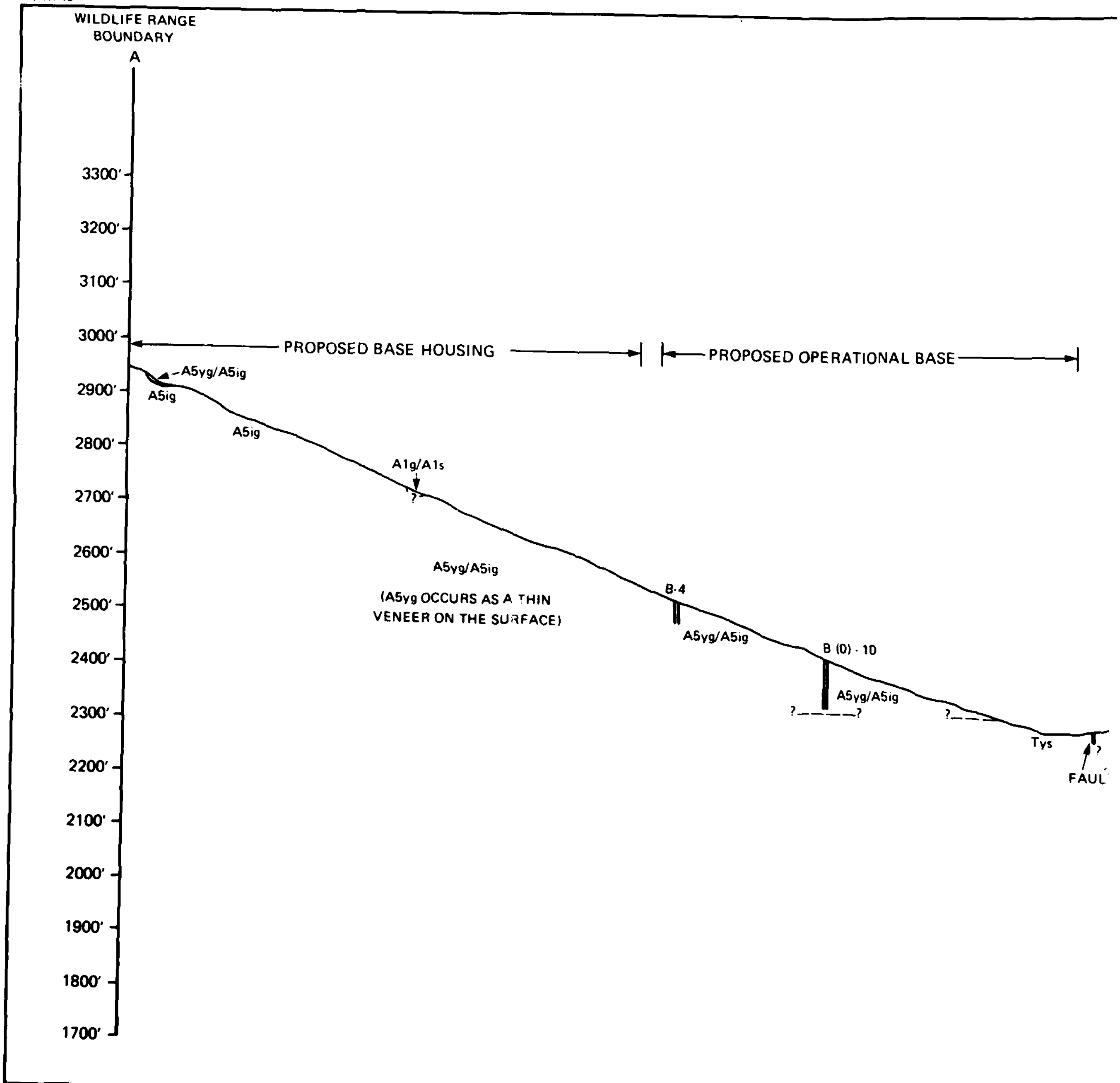
- Intermediate Age (A5i) and Older (A5o) Deposits - These deposits are thickest near the valley margin, where they are estimated to be about 100 feet (30 m) thick. Their thickness decreases toward the axis of the valley. At the proposed site, they are estimated to be from 40 to 80 feet (12 to 24 m) thick.

- Young Alluvial Deposits (A5y) - This unit appears to consist of a relatively thin veneer a few feet thick overlying the older basin-fill units.

5.3.2 Subsurface Soils

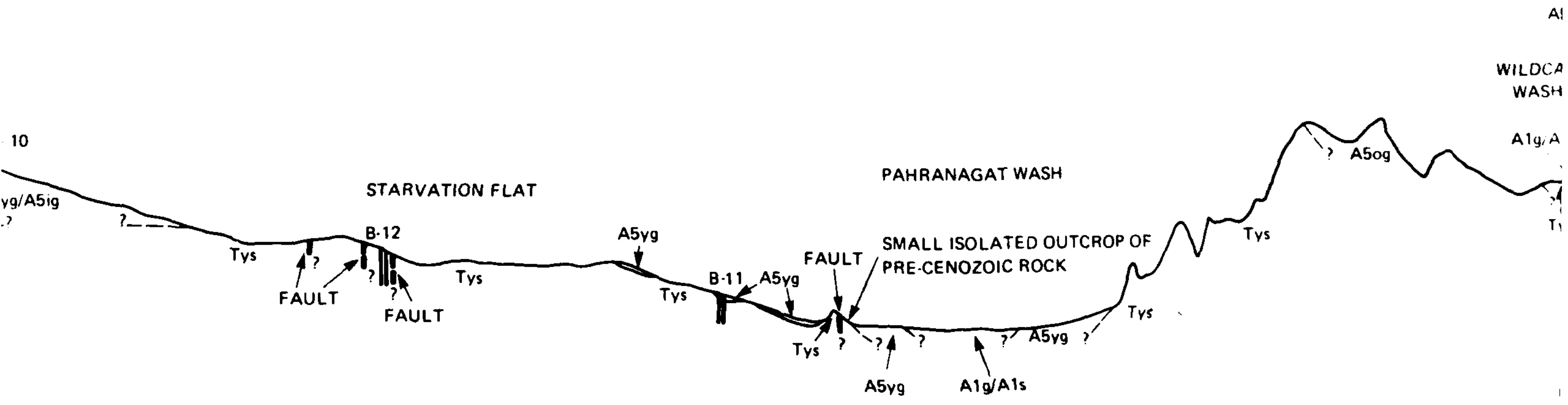
Two cross sections showing typical subsoil conditions are shown in Figures 5-1 and 5-2. Within the MOB and OBTS areas, a layer of sandy gravel with an estimated minimum thickness of 60 feet (18 m) of either young, intermediate, or older age alluvial fan deposits overlie the Tertiary lake sediments, which consist predominantly of sand and silt. The sandy gravel

FN TR-43

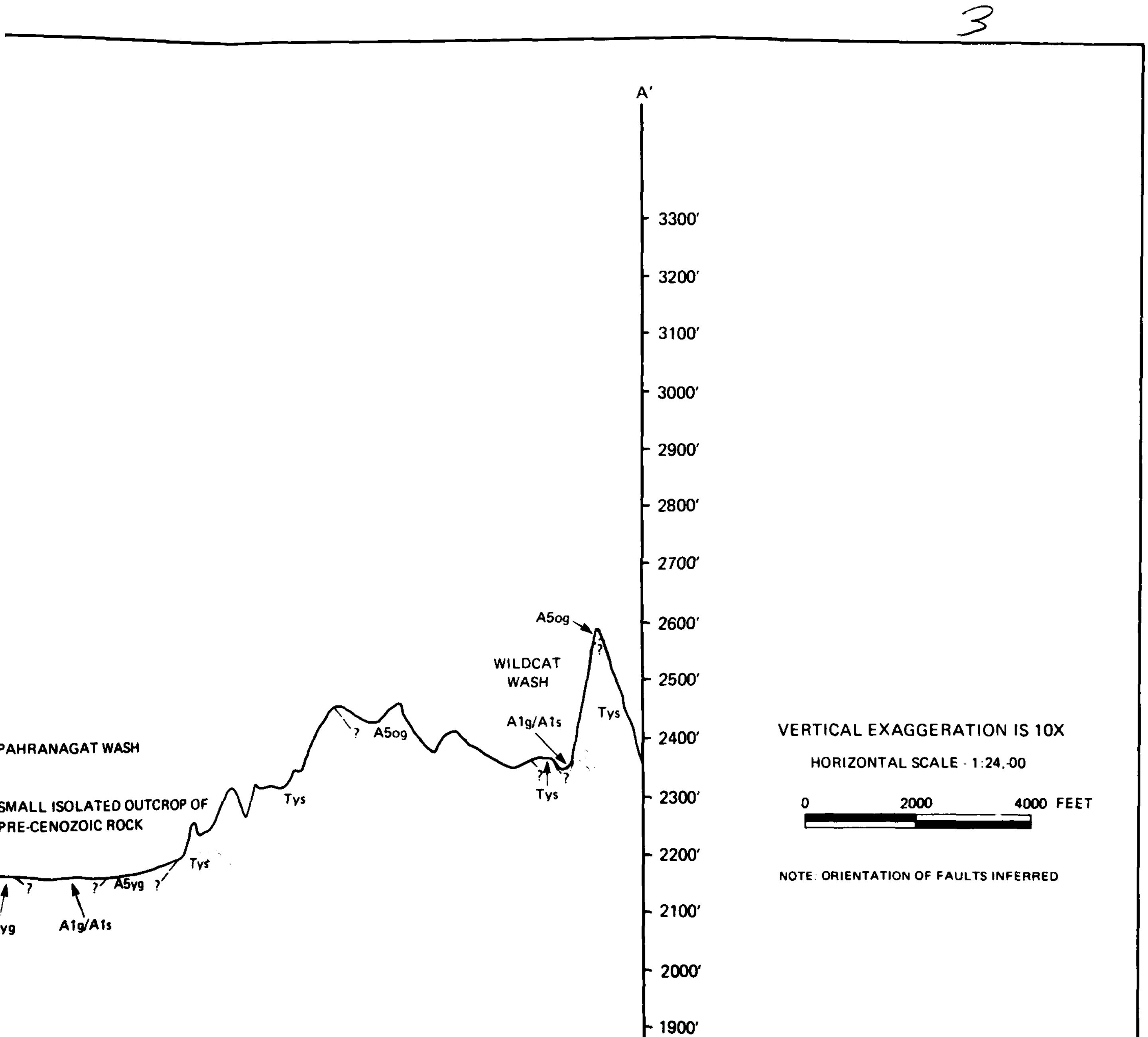


23 DEC 80

IONAL BASE



10
yg/A5ig
STARVATION FLAT
B-12
Tys
FAULT
FAULT
A5yg
Tys
B-11
A5yg
FAULT
PAHRANAGAT WASH
SMALL ISOLATED OUTCROP OF
PRE-CENOZOIC ROCK
Tys
A5yg
A1g/A1s
A5yg
Tys
Tys
A5og
WILDCA
WASH
A1g/A



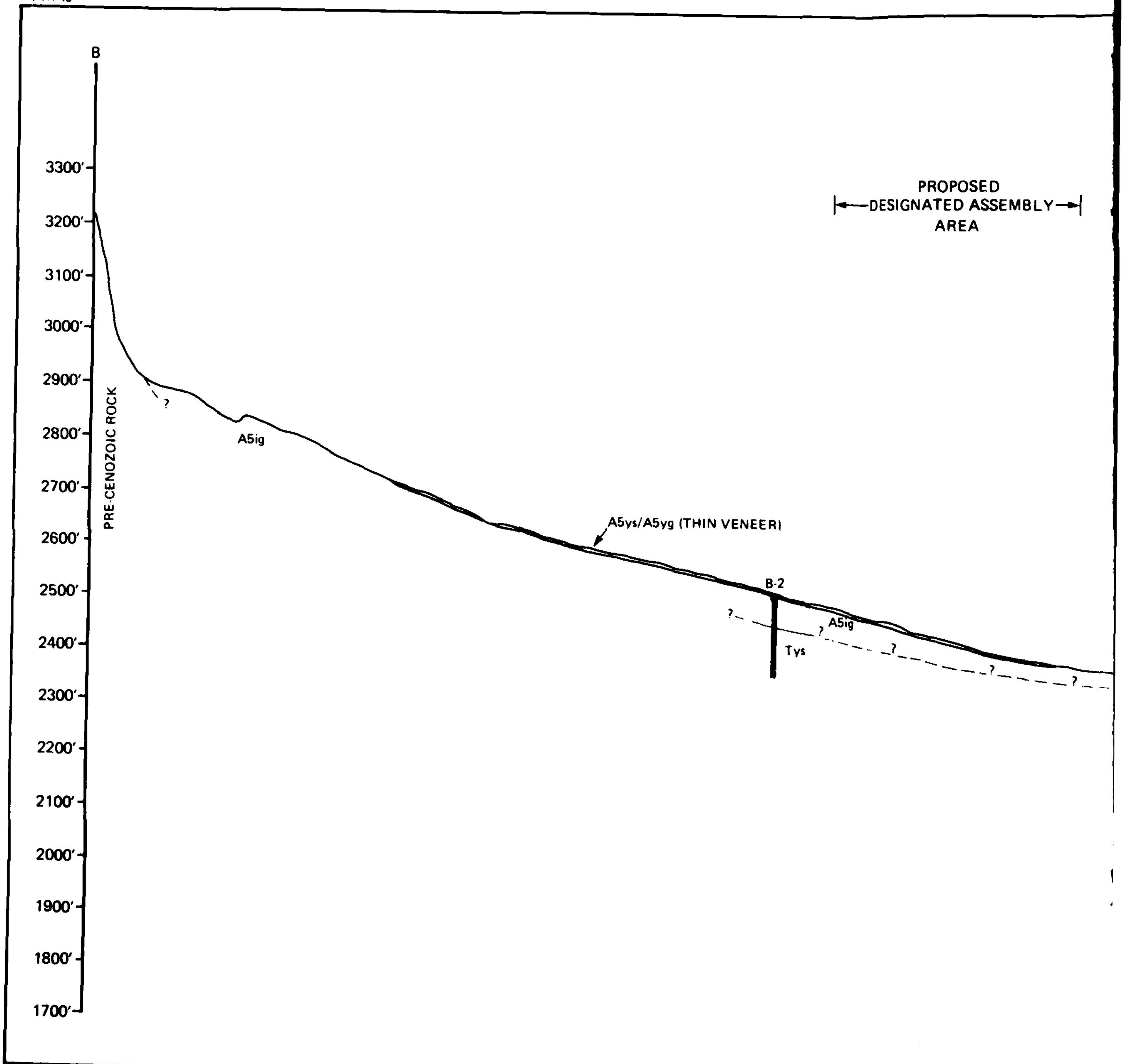
CROSS–SECTION A–A'
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 5-1

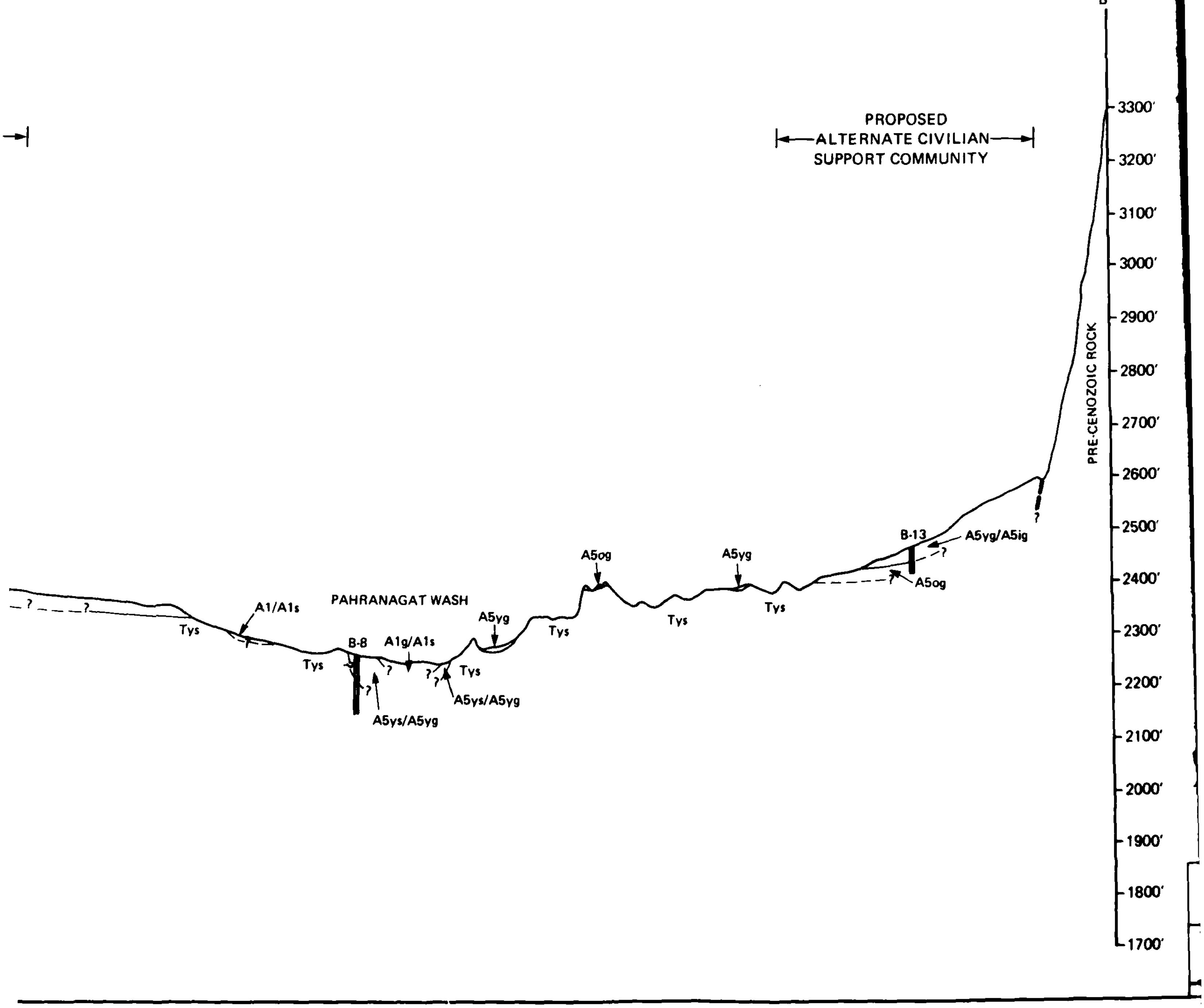
FUGRO NATIONAL, INC.

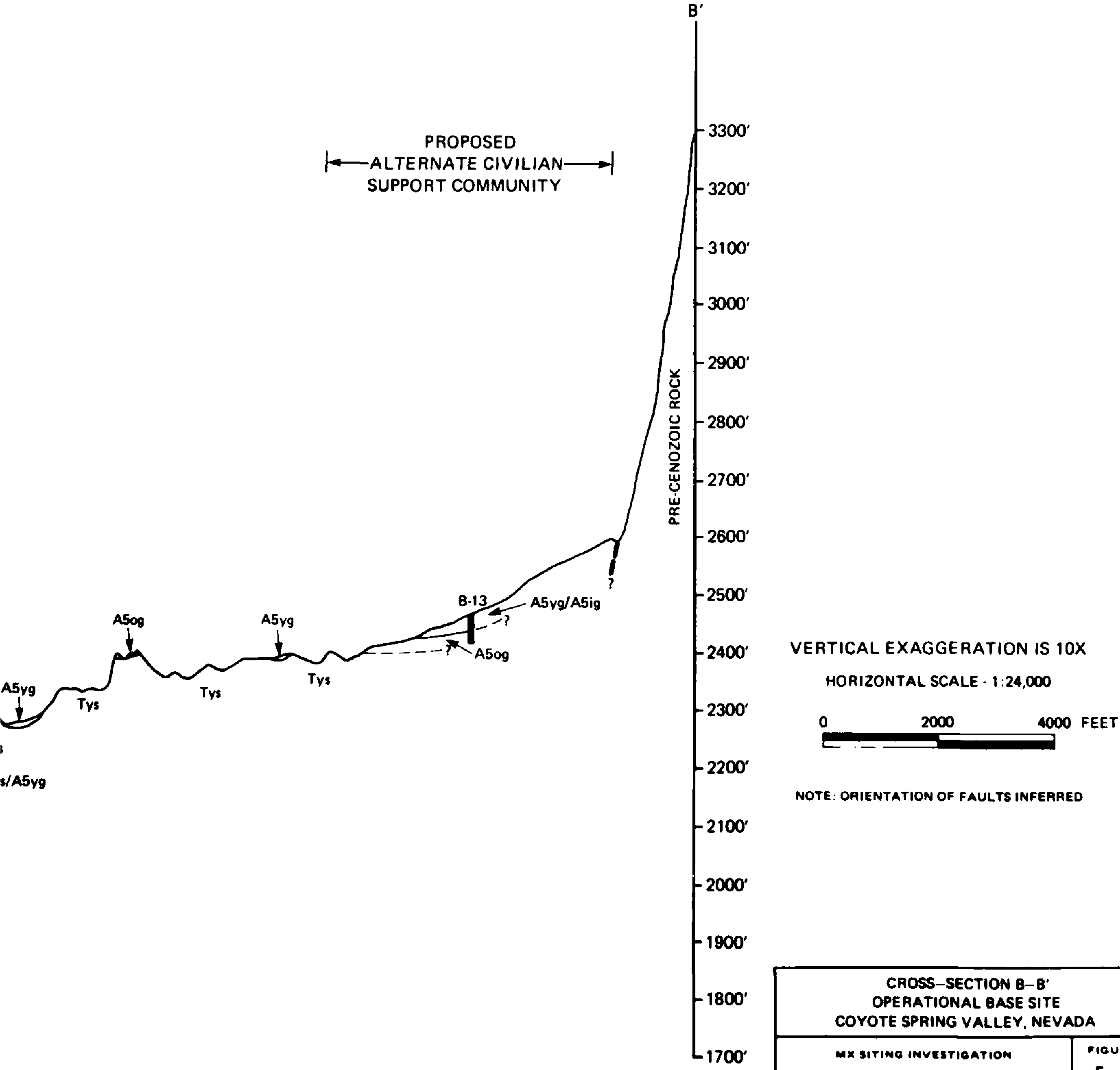
FN-TR-43



23 DEC 80

2


B'
PROPOSED
ALTERNATE CIVILIAN
SUPPORT COMMUNITY
PRE-CENOZOIC ROCK
3300'
3200'
3100'
3000'
2900'
2800'
2700'
2600'
2500'
2400'
2300'
2200'
2100'
2000'
1900'
1800'
1700'
B-13
A5yg/A5ig
A5og
A5og
A5yg
A5yg
PAHRANAGAT WASH
A1/A1s
Tys
B-8
A1g/A1s
A5ys/A5yg
A5ys/A5yg



CROSS–SECTION B–B'
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 5-2

FUGRO NATIONAL, INC.

is estimated to have a minimum thickness of about 40 feet (12 m) under the proposed DAA. The physical properties of these subsoils are summarized in Table 5-1. The descriptions of these soils are given below:

- Gravel (GP, GM) - The gravel is fine to coarse, mostly poorly graded, and dense to very dense. The moisture content is extremely low except at some locations just above the lake deposits. The shape of the individual particles varies from subangular to subrounded. Data obtained from pits, borings, trenches, and observations made in deep incisions indicates that Stage I to Stage IV caliche cementation exists erratically throughout the gravels in numerous local zones and occasionally in continuous layers. Zones of Stage I and II caliche cementation are frequent from ground surface to a depth between 3 and 10 feet (0.9 and 3.0 m). The gravel has variable sand content (11 to 44 percent) and gradations. Gravelly sand lenses are also encountered in the gravel. Scattered cobbles and boulders are also present in this deposit.

- Sand (SW, SM) - The sand is fine to coarse and is poorly graded. It is very dense except at a few locations. Its moisture content ranges from 1.3 to 26.8 percent. The sand particles are subangular to subrounded. Occasional caliche cementation exists in the sand. Sand layers vary in thickness from 1 to 47 feet (0.3 to 14.3 m).

- Silt (ML, CL-ML) - The silt is hard and nonplastic with two to 48 percent sand and up to 22 percent gravel.Most samples have negligible amounts of clay. Silt layers vary from 1-1/2 to 47-1/2 feet (0.5 to 14.5 m) thick and are interbedded with the sand described above.

5.3.3 Depth to Rock

Boring and seismic refraction data, as well as regional geologic relationships, indicate that rock does not occur within 160 feet (49 m) of the surface below most of the proposed DAA and MOB sites. Since portions of the eastern boundary of the proposed OBTS site extend a few feet into the bedrock, shallow rock (within 150 feet [46 m] from the surface) will be encountered along the eastern portion of the OBTS area.

FN TR 43

SOIL DESCRIPTION	GRAVEL	SAND	
	Sandy GRAVEL	Silty SAND, gravelly SAND, clayey SAND	[illegible]
USCS SYMBOLS	GP, GP-GM, GM, GW, GW-GM	SM, SP-SM, SC-SM, SC	ML, ML [illegible]
DRY DENSITY pcf (kg/m^3)	101.7 - 139.1 (1629 - 2228) (20)	78.3 - 136.2 (1254 - 2182) (74)	72.2 - 1[illegible] (115[illegible] - [illegible]
MOISTURE CONTENT %	1.0 - 6.3 (21)	1.3 - 26.8 ([illegible])	8.7 - 3[illegible]
DEGREE OF CEMENTATION	WEAK TO STRONG	NONE TO STRONG	NONE [illegible]
COBBLES 3 - 12 INCHES (8 - 30 cm)	0 - 20	0 - 2	0
GRAVEL %	37 - 86 (33)	0 - 48 (53)	0 - 22
SAND %	11 - 44 (33)	40 - 90 (53)	2 - 48
SILT AND CLAY %	2 - 32 (33)	3 - 49 (53)	52 - 98
LIQUID LIMIT	NDA	23 - 37 (12)	26 - 44
PLASTICITY INDEX	NP (1)	NP - 14 (12)	NP - 19
COMPRESSIONAL WAVE VELOCITY fps (mps)	1450 - 8000 (442 - 2439)	1540 (469) (1)	NDA

NOTES ( ) NUMBER OF TESTS PERFORMED
NDA NO DATA AVAILABLE (INSUFFICIENT DATA)
NP NON PLASTIC

PHYS[illegible]
[illegible]

M X [illegible]
DEPARTME[illegible]

FUGR[illegible]

23 DEC 80

	GRAVEL	SAND	SILT
	Sandy GRAVEL	Silty SAND, gravelly SAND, clayey SAND	Sandy SILT, SILT
	GP, GP-GM, GM, GW, GW-GM	SM, SP-SM, SC-SM, SC	ML, ML-CL
m^3)	101.7 - 139.1 (1629 - 2228) 20	78.3 - 136.2 (1254 - 2182) [74]	72.2 - 115.9 (1157 - 1857) 41
	1.0 - 6.3 [21]	1.3 - 26.8 [77]	8.7 - 39.3 [41]
	WEAK TO STRONG	NONE TO STRONG	NONE TO STRONG
	0 - 20	0 - 2	0
	37 - 86 33	0 - 48 [53]	0 - 22 [27]
	11 - 44 32	40 - 90 [53]	2 - 48 [27]
	2 - 32 33	3 - 49 [53]	52 - 98 [27]
	NDA	23 - 37 [12]	26 - 44 [11]
	NP [1]	NP - 14 [12]	NP - 19 21
(mps)	1450 - 8000 (442 - 2439)	1540 (469) [1]	NDA

PHYSICAL PROPERTIES OF SUBSOILS
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

Table 5.1

FUGRO NATIONAL, INC.

A deep seismic refraction survey was run along State Route 7 between Pahranagat Wash and U.S. 93. No rock was detected at depths less than 250 feet (76 m) and, along most of the line, rock was considerably deeper. Near the intersection of State Route 7 and U.S. 93 rock is greater than 1500 feet (457 m) below the surface.

An isolated outcrop of limestone-dolomite occurs about 1-1/2 miles (2.4 km) north of State Route 7 approximately 2000 feet (610 m) west of Pahranagat Wash (Drawing 5-1). This outcrop is about 1800 feet (545 m) and 4000 feet (1212 m) from the eastern margins of the proposed MOB and DAA, respectively. It is about 2200 feet (666 m) east of the proposed runway. A remote possibility exists that bedrock may be encountered at depths of less than 150 feet (45 m) in the extreme eastern portions of the DAA and MOB.

5.3.4 Depth to Water

Data obtained from published literature and from Fugro National, Inc. borings and observation wells indicate that the water table below all of the planned OB activity centers is probably greater than 300 feet (91 m).

Eakin (1964) indicates that a well drilled in the southern end of Coyote Spring Valley along State Route 7 encountered water at a depth of 332 feet (101 m). A well drilled in the northern portion of the valley about 8 miles (13 km) north of the intersection of Pahranagat and Kane Springs washes encountered water at a depth of 416 feet (127 m). Eakin (1964) also indicates that the depth to water in lower Kane Springs Valley is probably on the order of 300 to 400 feet (92 to 122 m) below the land surface. Five Fugro National, Inc., observation wells with depths between 50 and 160 feet (15 and 49 m) were drilled in Coyote Spring Valley. No water was encountered in any of these wells. The previously mentioned (Section 5.3.1) hydrology well drilled by Fugro National encountered water at 547 feet (160 m) below the surface.

5.4 DRAINAGE AND TERRAIN

Coyote Spring and Kane Springs valleys are characterized by major axial drainages, Pahranagat Wash and Kane Springs Wash, respectively. These axial washes are flanked by numerous tributaries which partially dissect the valley-fill sediments. Kane Springs Wash drains southwesterly and joins Pahranagat Wash just east of U.S. Highway 93. Pahranagat Wash drains southerly to the vicinity of State Route 7, where it turns southeasterly and exits the valley between the northern Arrow Canyon Range and the southern Meadow Valley Mountains. It eventually joins the Muddy River to the south. Both Pahranagat and Kane Springs washes are ephemeral and have surface water runoff only after periods of heavy rainfall.

Terrain conditions in the site area range from deeply incised "badlands" topography to areas of relatively smooth surfaces. Incision depths range from less than a foot (0.3 m) to greater than 130 feet (39.6 m). Terrain characteristics are generally controlled by the underlying basin-fill sediments.

Terrain and drainage conditions are shown in Drawing 5-2.

5.4.1 "Badlands" Areas

Most of the areas where late Tertiary sediments are exposed have developed a "badlands" topography characterized by fine drainage networks with high drainage density. In these areas, the maximum drainage depth is about 200 feet (61 m) with an average depth of about 20 feet (6 m). Divides between incisions are relatively smooth, nearly flat surfaces which have a slope of about two to three degrees.

5.4.2 "Deeply Incised" and "Rolling" Terrain

The terrain in areas where intermediate (A5i) and older (A5o) age alluvial fan deposits occur ranges from relatively smooth planar surfaces with widely spaced incisions to areas of "rolling" topography. The maximum drainage depth in these areas is about 30 feet (9 m) with an average of about 10 feet (3 m). Except in the areas of "rolling" terrain, divides between incisions are generally flat and have an average slope of about one degree.

5.4.3 "Active" Alluvial Fan Surfaces

Areas underlain by young alluvial fans (A5y) are characterized by numerous, closely spaced shallow channels which range in depth from less than a foot (0.3 m) to a maximum of about 10 feet (3.0 m), with an average depth of about 3 feet (0.9 m). The fan surfaces are very uneven due to abundant linear concentrations of cobbles and boulders.

5.5 GEOLOGIC HAZARDS

Geologic hazards discussed below include flooding, faults and seismicity, and rockfall.

5.5.1 Flooding

Our evaluation of the flood potential for the site area consisted of aerial photo analysis and limited field observations. No hydrographic studies or calculations were performed.

The aerial photo analysis consisted of reviewing the drainage patterns and determining which stream channels appear to be recently active (would contain water during a rainstorm).

The field observations were aimed at determining which channels appear most active based on channel features such as whether they contain linear accumulations of cobbles and boulders and the size of the accumulations, presence and condition of plants and trees that may be growing in the channels, and whether foreign debris had been washed into the channels.

Most of the larger channels contain linear accumulations of cobbles and boulders. However, it appears that they are more pervasive and consist of larger rock fragments in the young alluvial fan channels and in channels within the "badlands" terrain than in most of the channels that cut the intermediate and old alluvial fan deposits. Based on this, it appears that drainages in the young alluvial fans and "badlands" are more likely to experience high velocity flooding than elsewhere in the study area. Scattered desert plants and small trees appear to be well established in most of A5ig and A5og incisions, which similarly confirms the lower flood potential of drainages in these units.

5.5.2 Faults and Seismicity

Several faults have been mapped and field checked on the aerial photographs within the site area. Most of them strike northerly or northeasterly. Ages of these faults are based on the age of the sediments which they displace. Late Quaternary faults are younger than 200,000 years and cut intermediate age alluvial fan deposits (A5i). Pliocene or younger faults are those that cut Tertiary lake sediments (Tys) or older alluvial fan deposits (A5o). The ages represent a maximum because the faults may be considerably younger than the sedimentary units they displace.

The Kane Springs Wash fault, which strikes northeasterly along the southeastern margin of Kane Springs Valley, is the only fault shown on published geologic maps that cuts basin fill within the area mapped. Aerial photos show several scarps that appear to offset Quaternary alluvial fan deposits. Most Quaternary faults in this region trend north-south. The Kane Springs Wash fault is not typical of Basin and Range tectonics, but more closely resembles the Pahranagat shear zone, a northeast-southwest trending zone of probable left lateral movement about 30 miles (48 km) north of the site area. Several other faults mapped on the aerial photos generally strike northerly through the site area. These faults appear to cut late Tertiary sediments, intermediate and/or older age alluvial fan deposits (Drawing 5-1). One of the more prominent northerly striking faults is located north of State Route 7 between Pahranagat Wash and "old" U.S. 93. The surface expression of this fault consists of a pronounced east-facing scarp that averages approximately 12 feet (3.7 m) in height. Most of the other faults show less pronounced west-facing scarps. To the south where the valley narrows, a prominent scarp can be traced northeasterly across the valley into the bedrock where it appears to die out. Most of this fault is south of the area mapped and only its northeast portion is shown on the geologic map.

The linear west side of the Meadow Valley Range suggests that it is bounded in part by a major basin-bounding fault system. Short discontinuous segments of the fault were mapped adjacent to or at the rock/basin fill contact. This fault zone appears to be up to a mile wide and displaces young age alluvial fan deposits. Some fault traces project through the test and training site and the two optional base housing centers. Photo lineaments trending subparallel to the fault traces may be structurally associated with the fault zone.

Several north-south trending lineaments were mapped on the aerial photos in Coyote Spring Valley and are shown the geologic map (Drawing 5-1). They occur in the A5i and A5o units. Field observations indicate that at least some of the lineaments are not faults. No indications of lateral or vertical displacement were observed. Those lineaments observed in the field appear to consist of near-vertical caliche-filled fractures or "cracks." Similar features in nearby valleys are attributed to differential compaction of underlying late Tertiary lake deposits (Ealey, 1963).

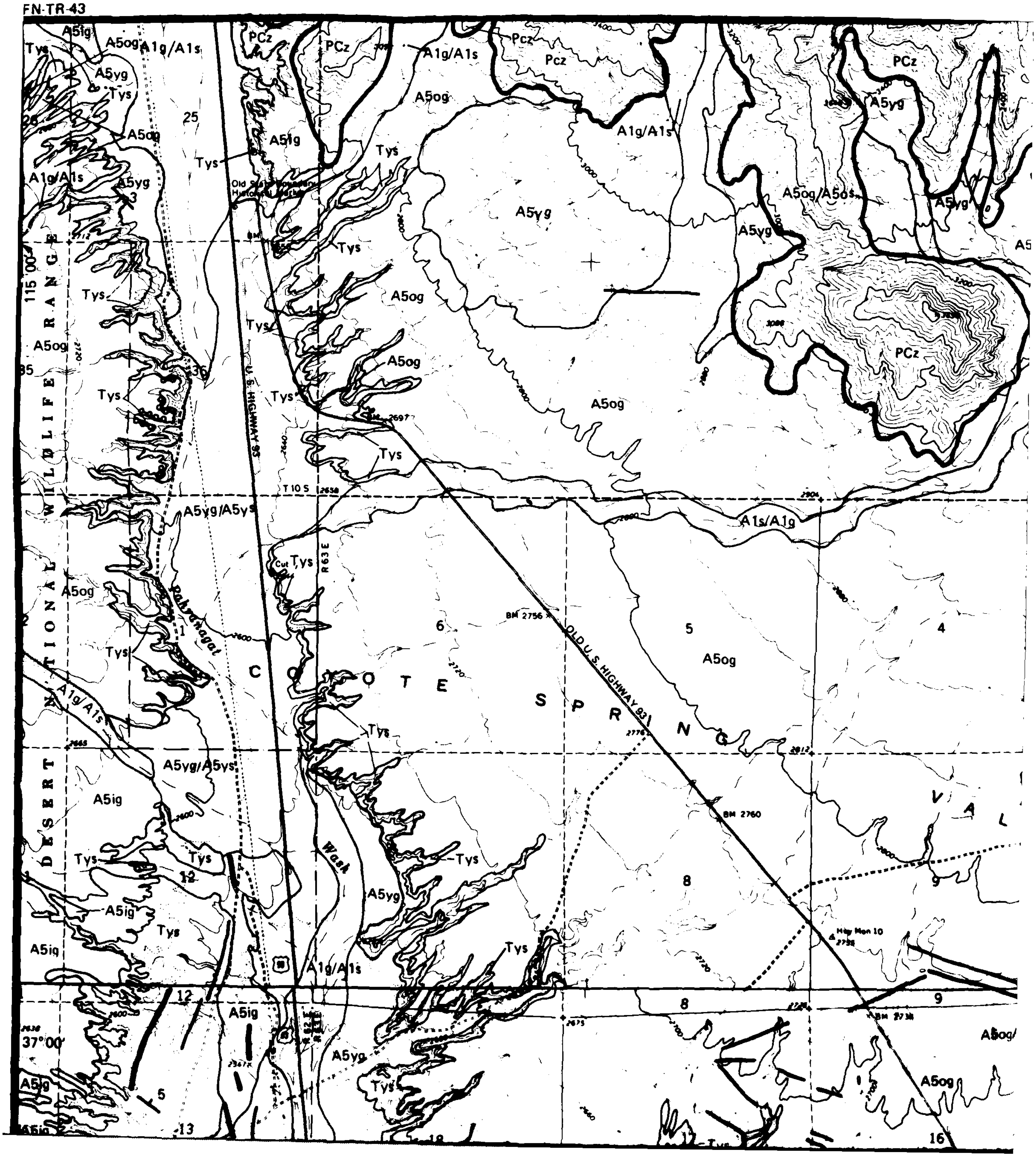
The OB site is situated within the Southern Nevada Tranverse Zone (SNTZ) which is a southwestern extension of the Inter-Mountain Seismic Belt (Fugro National, 26 March 1980, pp. 58-59). The SNTZ is characterized by an abundance of northeast-southwest trending strike slip faults and by crude clustering and alignments of seismic events within a wide zone.

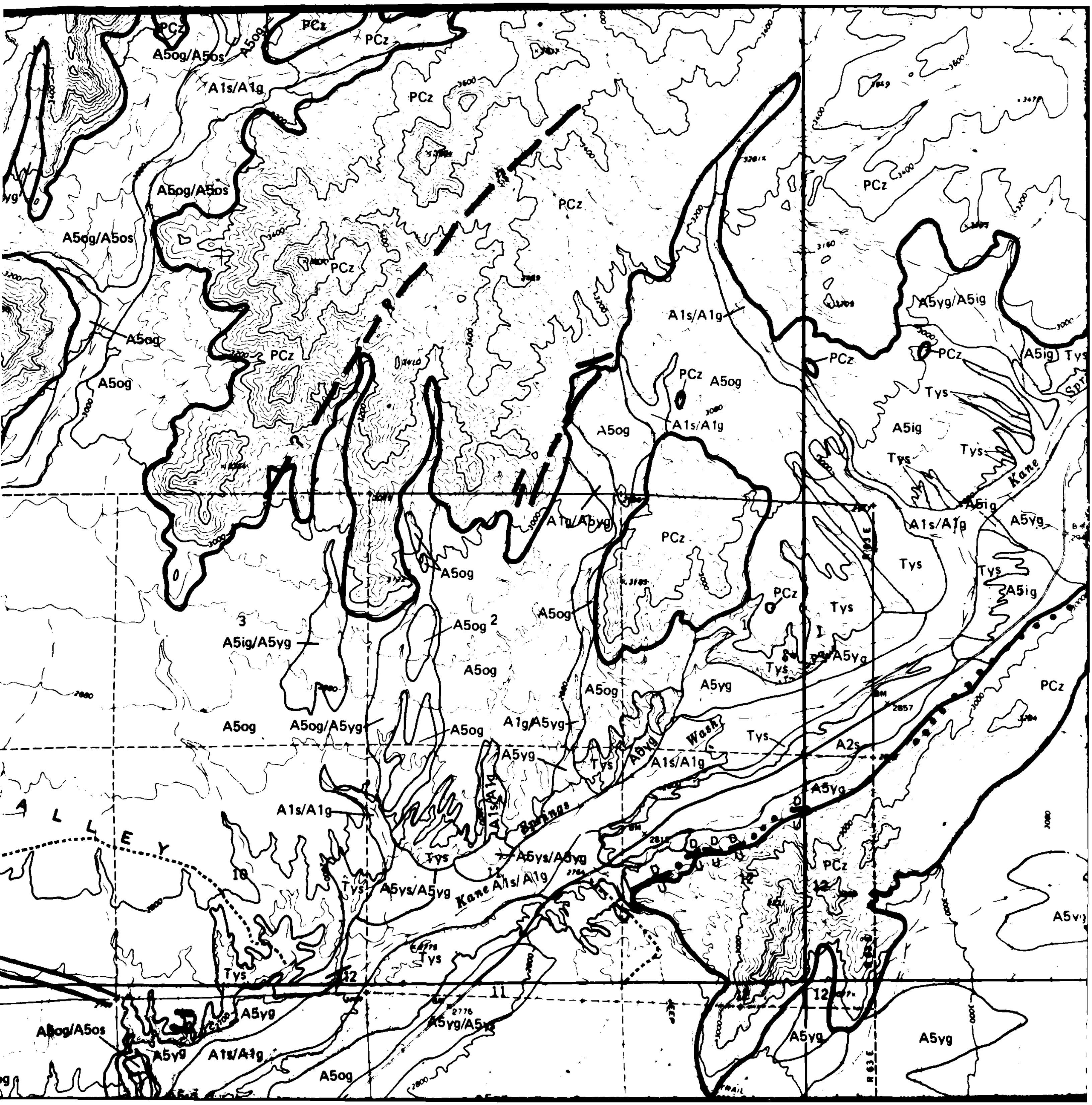
Seismicity in the site area itself has been relatively low with only one or two events of magnitude less than 3 occurring locally (Drawing 5-3). An earthquake of magnitude 6.1 occurred about 50 miles (80 km) northeast of the OB areas and within the SNTZ in 1965.

5.5.3 Rockfall

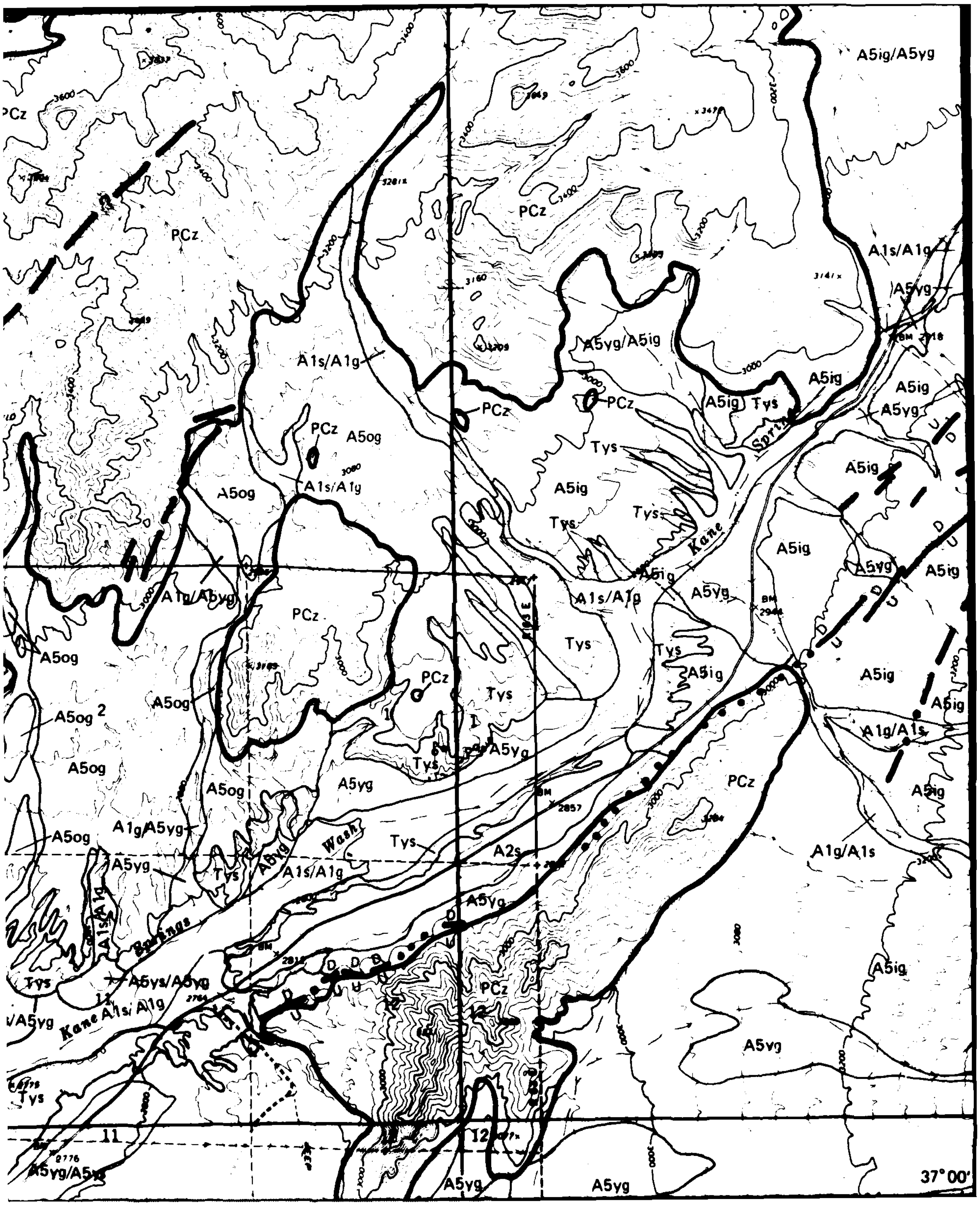
Large near-vertical joints occur in the mountain front along the eastern side of Coyote Spring Valley. Some of these joints appear to be several feet wide and several tens of feet long and represent planes of weakness in the bedrock along which large fragments of rock could break off. However, no anomalously large boulders, rock fragments, or rockfall talus accumulations were observed along the mountain front.

Mountain fronts along Kane Springs Valley and along the western side of Coyote Spring Valley are less steep than along the east side of Coyote Spring Valley. No major joints were observed along these mountain fronts.


DESERT NATIONAL WILDLIFE RANGE
COYOTE SPRING VAL
U.S. HIGHWAY 93
OLD U.S. HIGHWAY 93
Pahranagat
Wash
Old State Boundary Historical Marker
115°00'
37°00'
T 10 S
R 63 E
BM 2756
BM 2760
BM 2734
Hwy Mon 10
A5ig
A5og
A5yg
A1g/A1s
A1s/A1g
A5og/A5os
A5yg/A5ys
PCz
Pcz
Tys
25
36
1
12
13
5
6
4
8
9
16

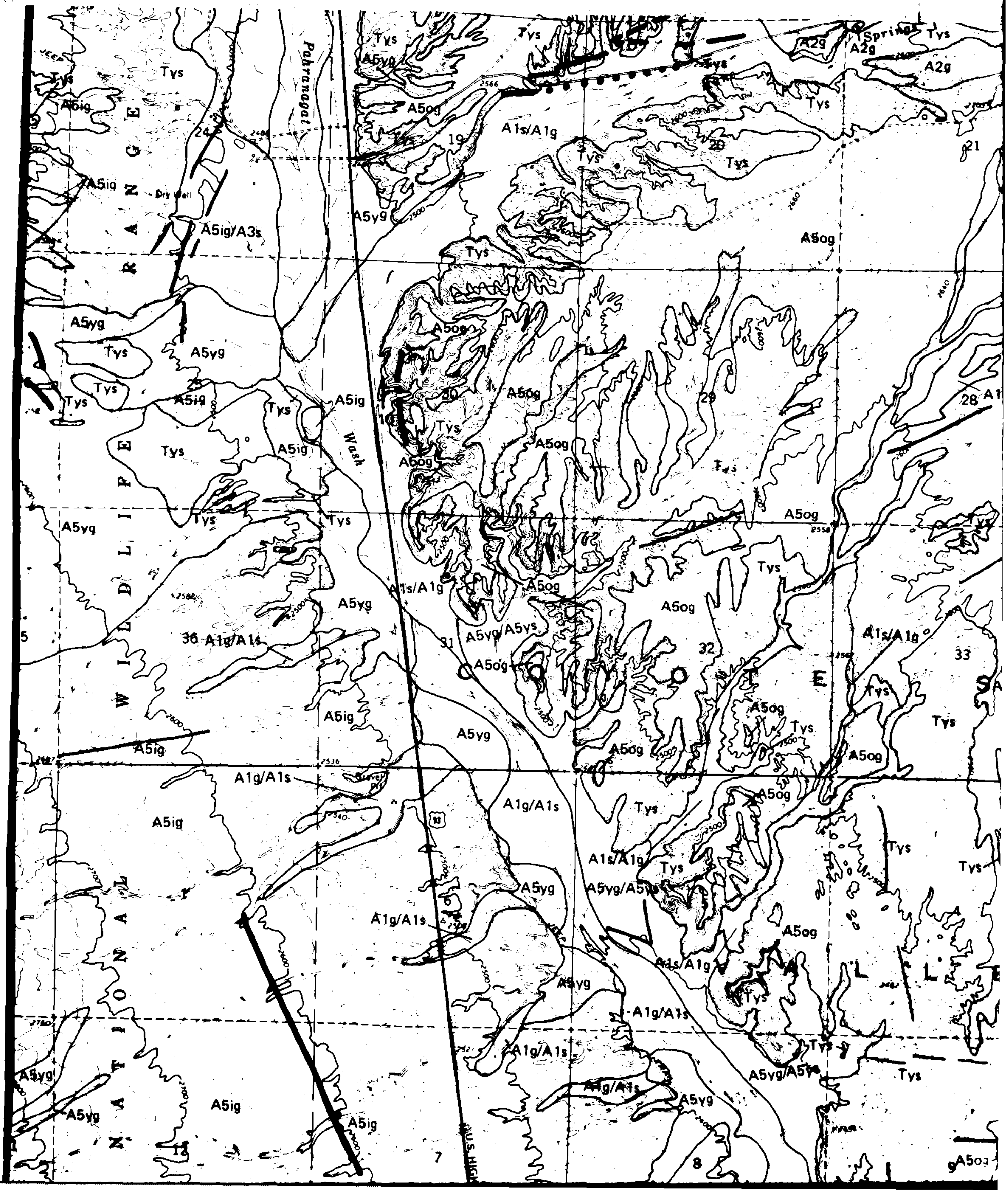


PCz
A5og/A5os
A1s/A1g
A5og
A5yg/A5ig
A5ig
Tys
Kane
A1s/A1g
A1g/A5yg
A5ig/A5yg
A5og/A5yg
A5yg
A2s
A1s/A1g
A5ys/A5yg
Kane
Springs
Wash
V A L L E Y
A5yg/A5yg
R 62 E
R 63 E
TRAIL
3
2
10
11
12

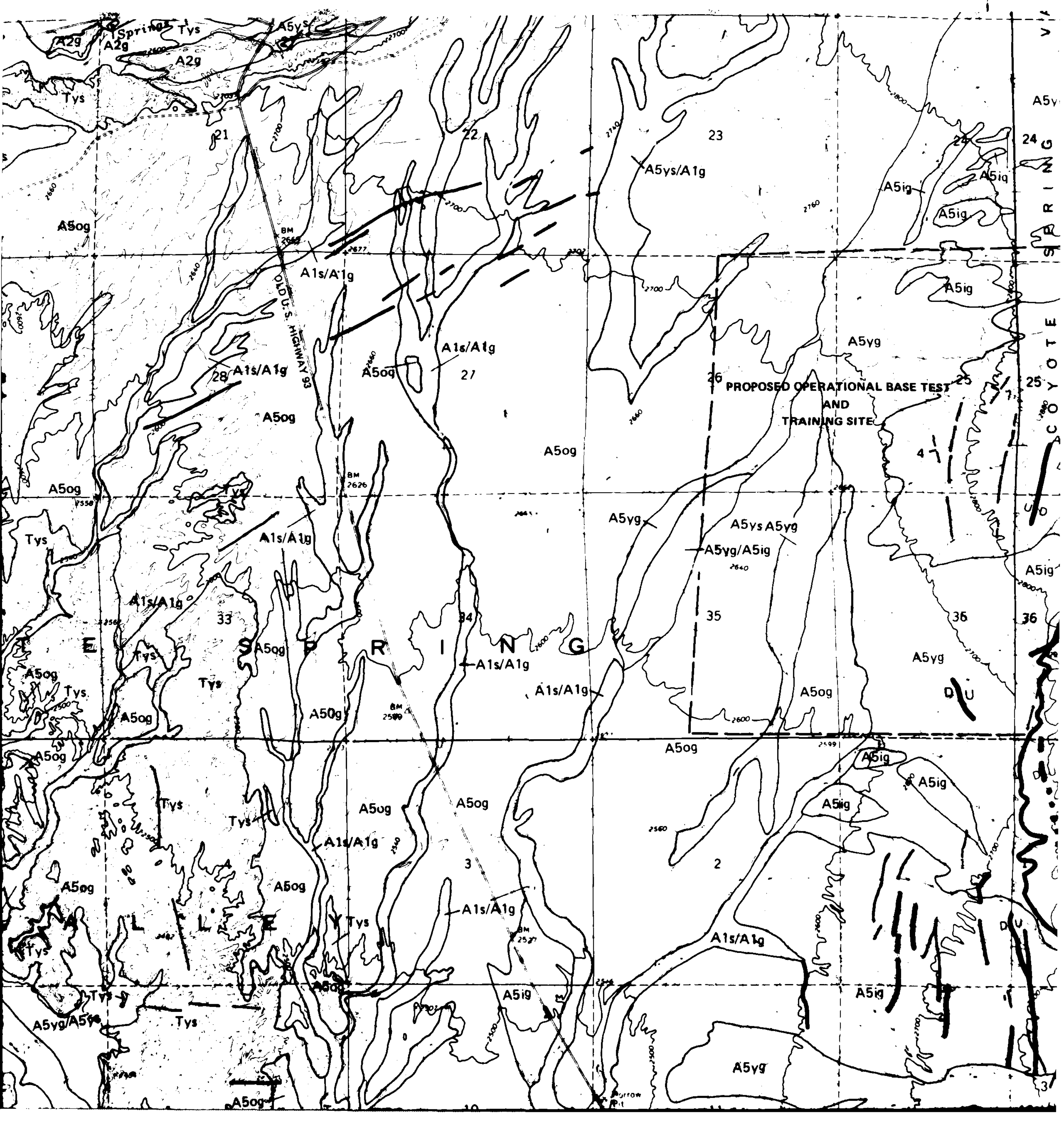


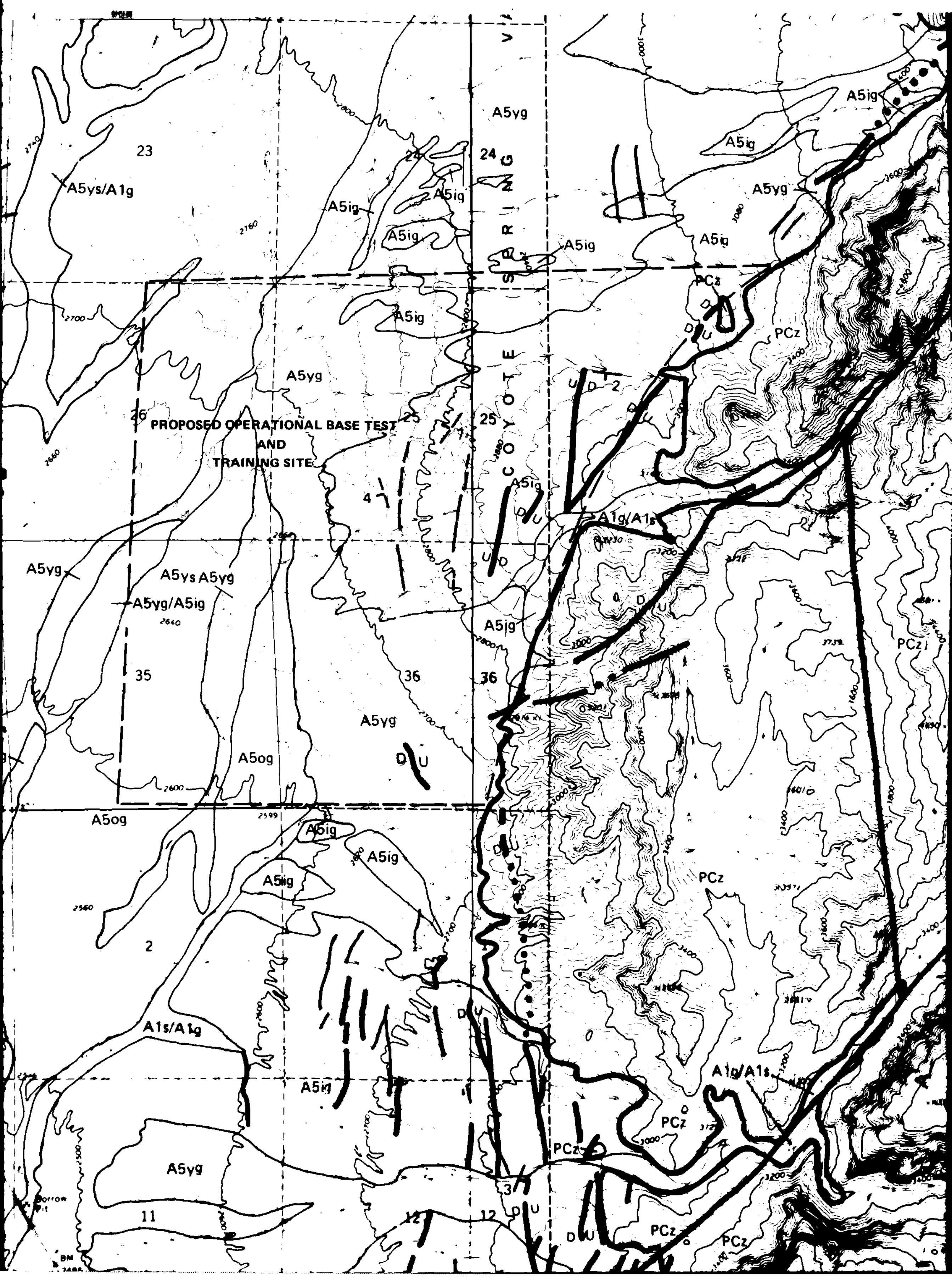
A5ig/A5yg
PCz
PCz
PCz
A1s/A1g
A5yg
A5yg/A5ig
A1s/A1g
PCz
A5og
PCz
A5ig
A5ig
Tys
A5yg
A1s/A1g
A5og
Tys
A5ig
Tys
Kane
Spring
A5ig
A1g/A5yg
PCz
A1s/A1g
A5yg
A5og
Tys
A5ig
A5og
PCz
Tys
A5ig
A5ig
A5og
A5yg
A5og
A5yg
A1g/A1s
A5og
A1g A5yg
Tys
Wash
PCz
A5ig
A5og
A5yg
Tys
A2s
A1g/A1s
A1s/A1g
A5yg
Springs
A5ig
Tys
A5ys/A5yg
PCz
/A5yg
Kane A1s/A1g
A5yg
Tys
11
12
A5yg/A5yg
A5yg
A5yg
37°00'

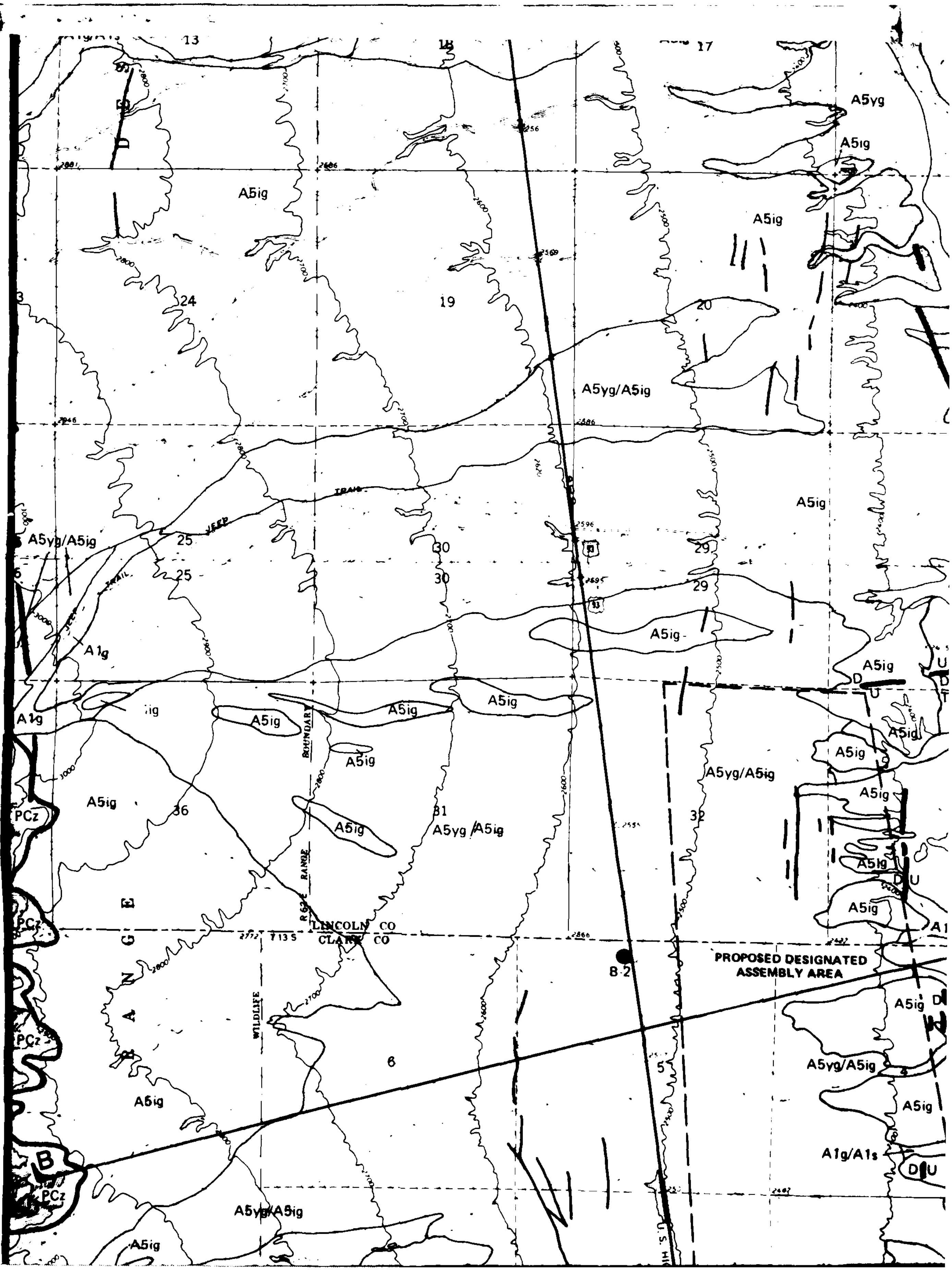
4



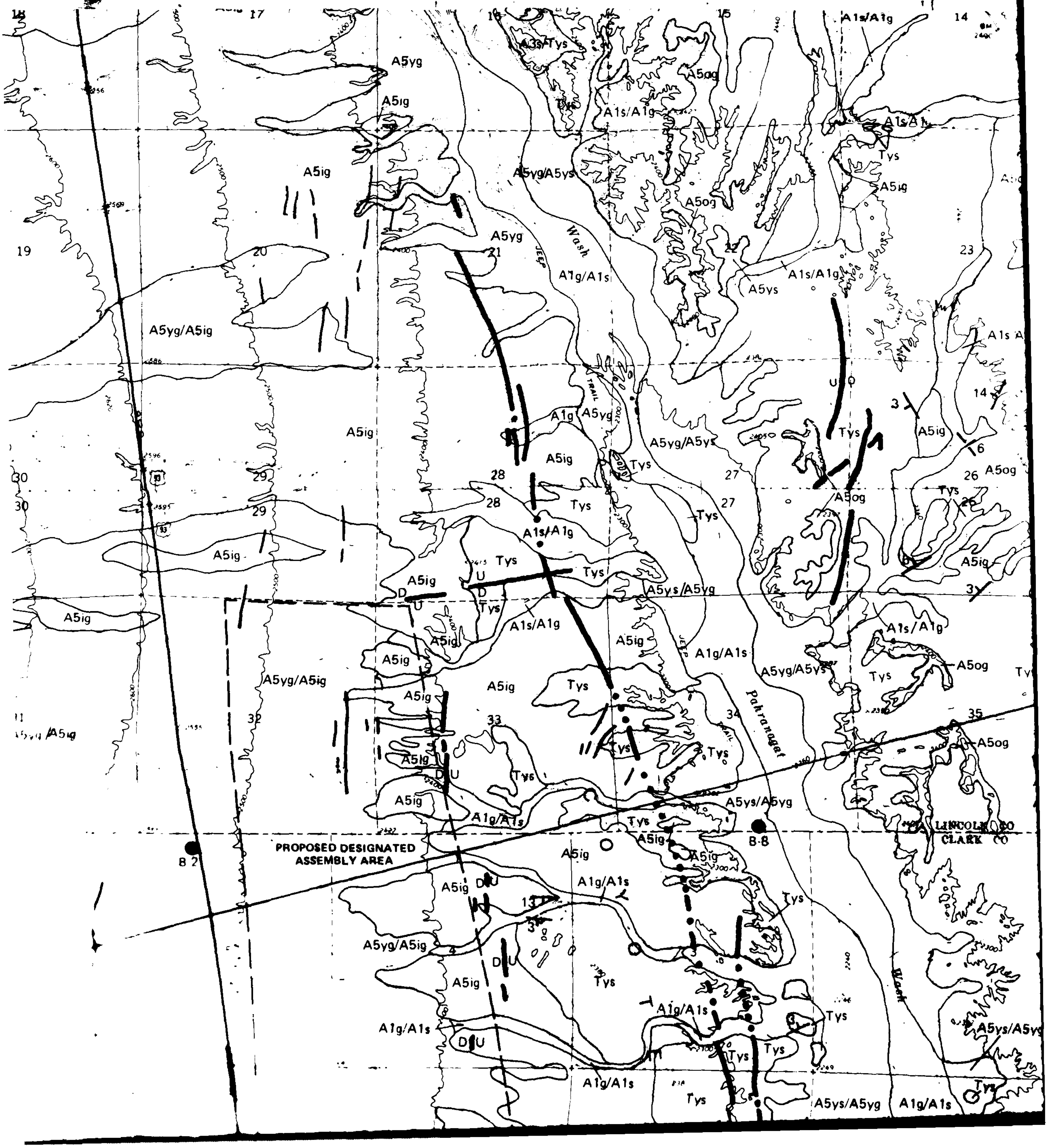
Tys
A5yg
Springs
A2g
A5ig
A5og
A1s/A1g
19
20
21
24
Pahranagat
Dry Well
A5ig/A3s
25
30
29
28
Wash
W I L D L I F E   R A N G E
36 A1g/A1s
31
A5yg/A5ys
32
33
A1g/A1s
Gravel Pit
A5yg/A5ys
N A T I O N A L
JEEP
12
7
8


PROPOSED OPERATIONAL BASE TEST
AND
TRAINING SITE
OLD U.S. HIGHWAY 93
Springs
A5ys/A1g
A1s/A1g
A5yg/A5ig
A5og
A5yg
A5ig
A5ys
Tys
A2g
S P R I N G
V A L L E Y
SPRING
COYOTE
BM 2665
BM 2626
BM 2527
21
22
23
24
25
26
27
28
33
34
35
36
2
3
4
2700
2600
2640
2660
2760
2800

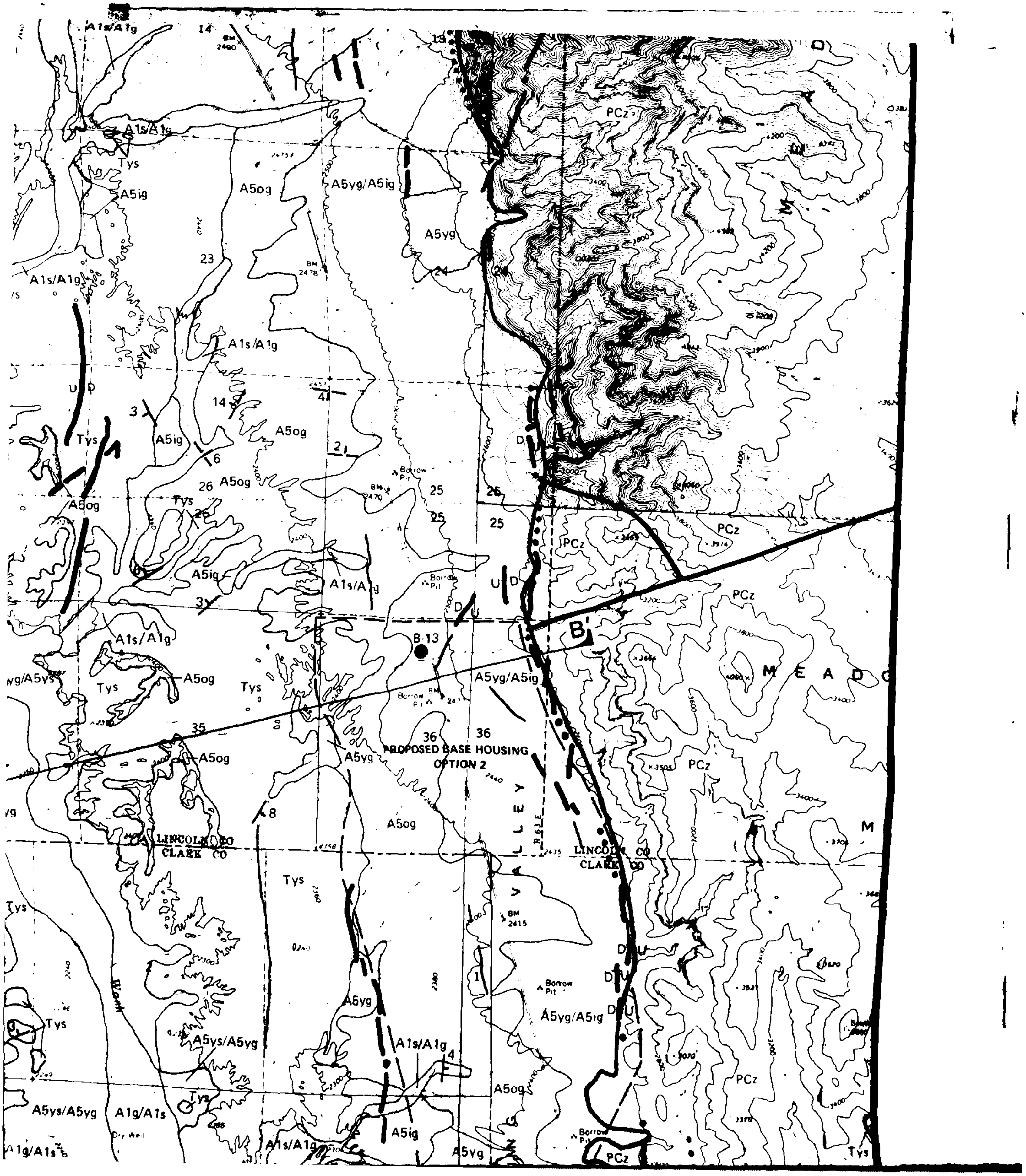

PROPOSED OPERATIONAL BASE TEST
AND
TRAINING SITE
COYOTE SPRING V
A5yg
A5ig
A5ys/A1g
A5ys A5yg
A5yg/A5ig
A5og
A1g/A1s
A1s/A1g
PCz
D U
23
24
25
26
35
36
2
11
12
Borrow Pit
BM



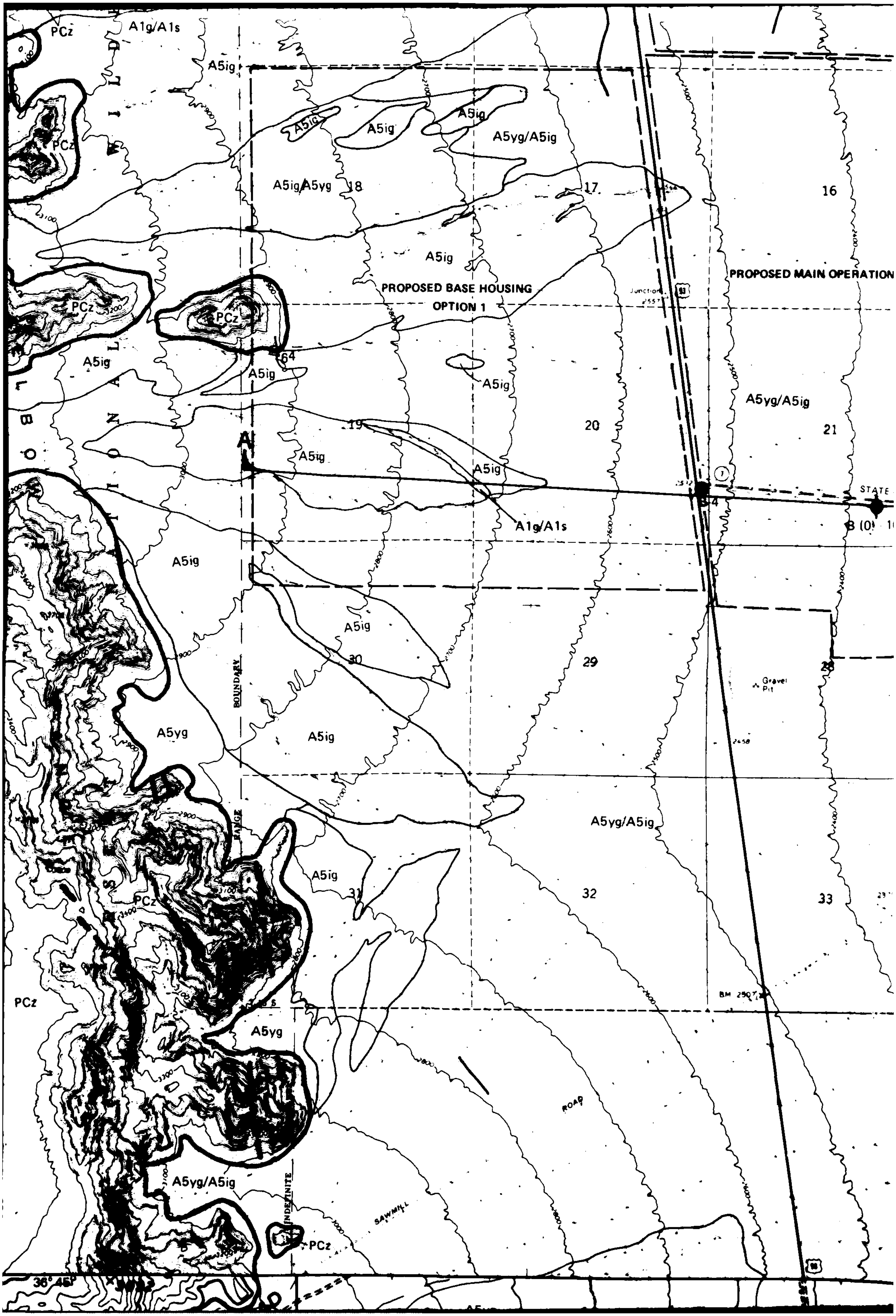
A5yg
A5ig
A5yg/A5ig
A1g
PCz
B
D
U
B-2
LINCOLN CO
CLARK CO
T13S
R62E
BOUNDARY
RANGE
WILDLIFE
TRAIL
JEEP
PROPOSED DESIGNATED
ASSEMBLY AREA
A1g/A1s



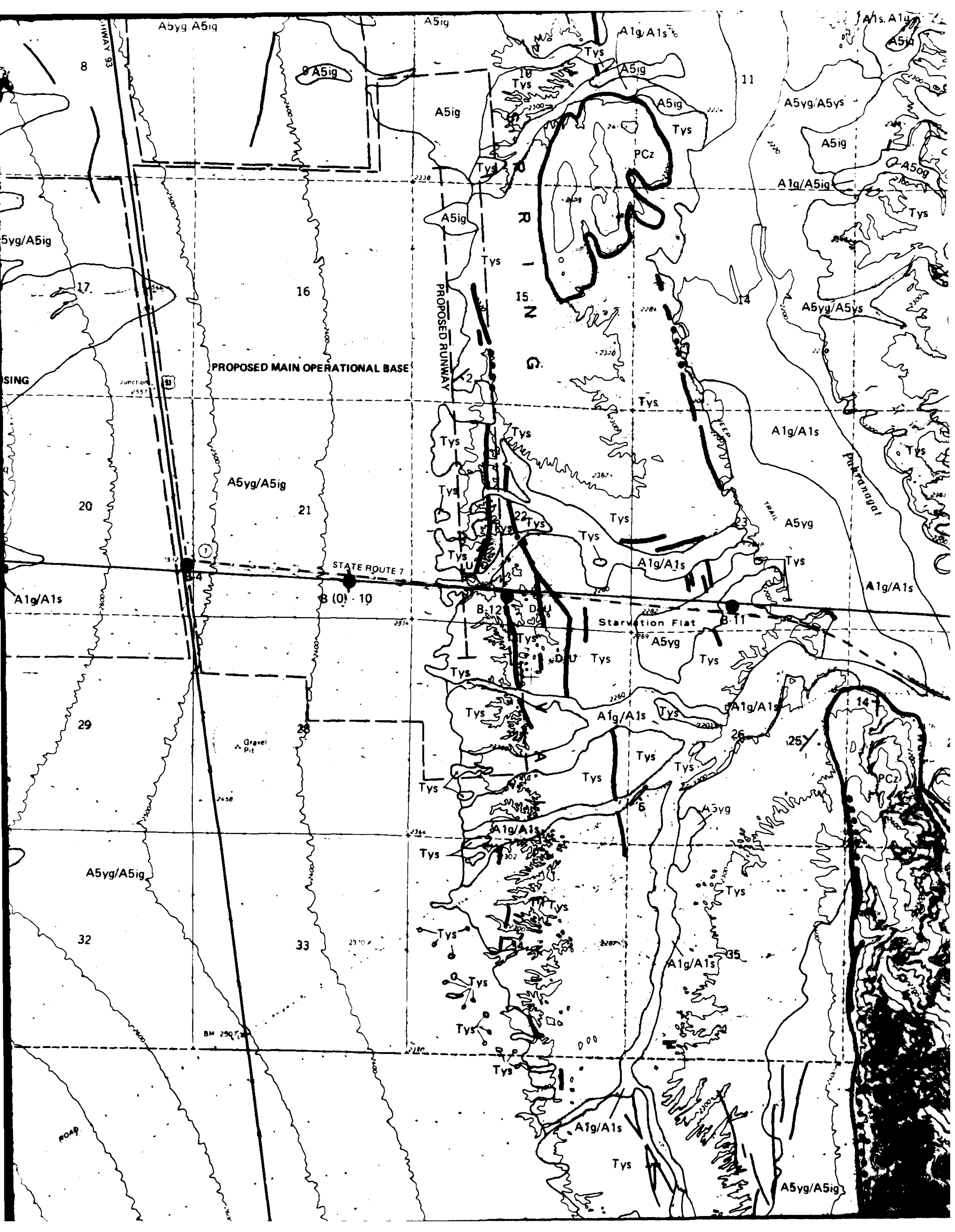
17
16
15
14
A1s/A1g
A3s/Tys
A5yg
A5og
A5ig
A1s/A1g
A1s/A1
Tys
A5ig
A5yg/A5ys
A5og
19
20
A5yg
21
Wash
JEEP
A1g/A1s
22
A5ys
A1s/A1g
23
A5yg/A5ig
A1s
TRAIL
U
A1g
A5yg
A5ig
A5yg/A5ys
Tys
3
A5ig
14
6
30
29
28
A5ig
Tys
27
A5og
26
A5og
30
29
28
Tys
Tys
27
A1s/A1g
A5ig
Tys
U
Tys
A5ig
D
U
D
Tys
A5ys/A5yg
3
A5ig
A1s/A1g
A1s/A1g
A5ig
A5ig
JEEP
A1g/A1s
A5yg/A5ys
A5og
A5yg/A5ig
A5ig
A5ig
Tys
Tys
Pahranagat
A5ig
33
34
35
32
A5og
A5yg/A5ig
A5ig
Tys
Tys
A5ig
D U
Tys
A5ig
A5ys/A5yg
A1g/A1s
Tys
B-8
A5ig
A5ig
LINCOLN CO
CLARK CO
PROPOSED DESIGNATED
ASSEMBLY AREA
8 2
A5ig
A5ig
D U
A1g/A1s
Tys
A5yg/A5ig
D U
A5ig
Tys
Wash
A1g/A1s
Tys
A1g/A1s
D U
Tys
Tys
A5ys/A5yg
A1g/A1s
Tys
A5ys/A5yg
A1g/A1s
Tys

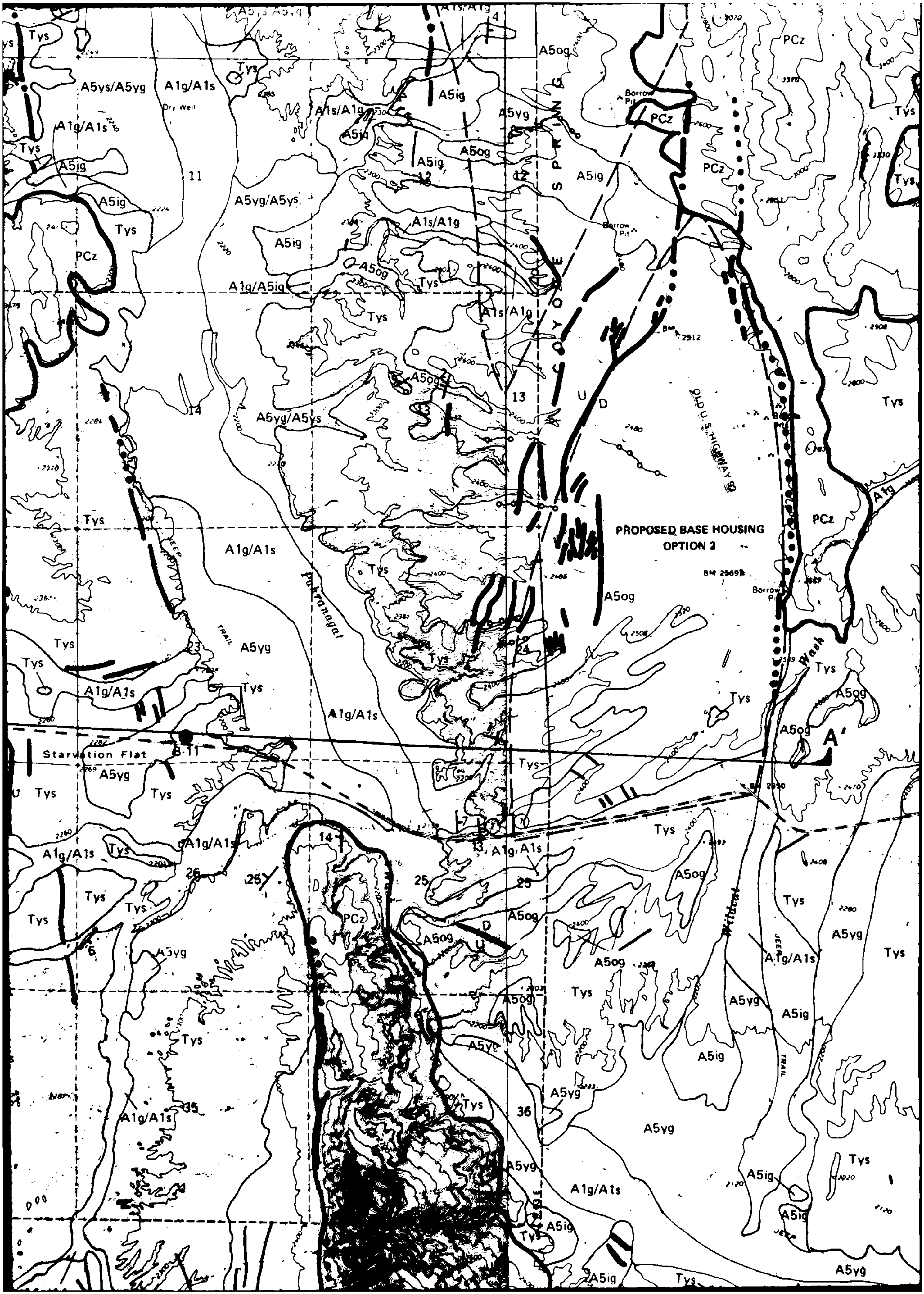


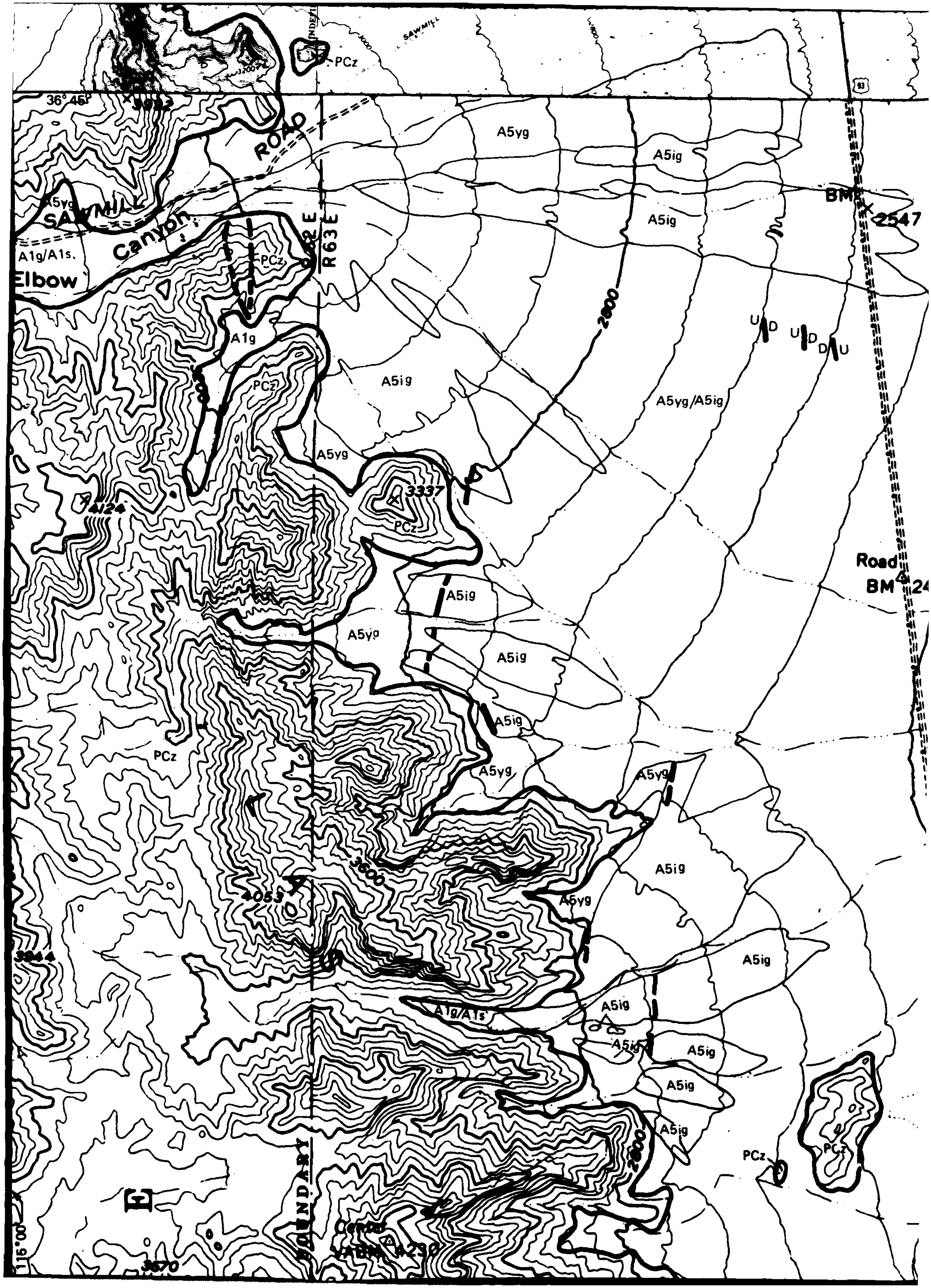
A1s/A1g
Tys
A5ig
A5og
A5yg/A5ig
A5yg
PCz
U D
D U
Borrow Pit
B-13
B'
PROPOSED BASE HOUSING
OPTION 2
LINCOLN CO
CLARK CO
VALLEY
MEADO
A5ys/A5yg
A1g/A1s
Dry Well



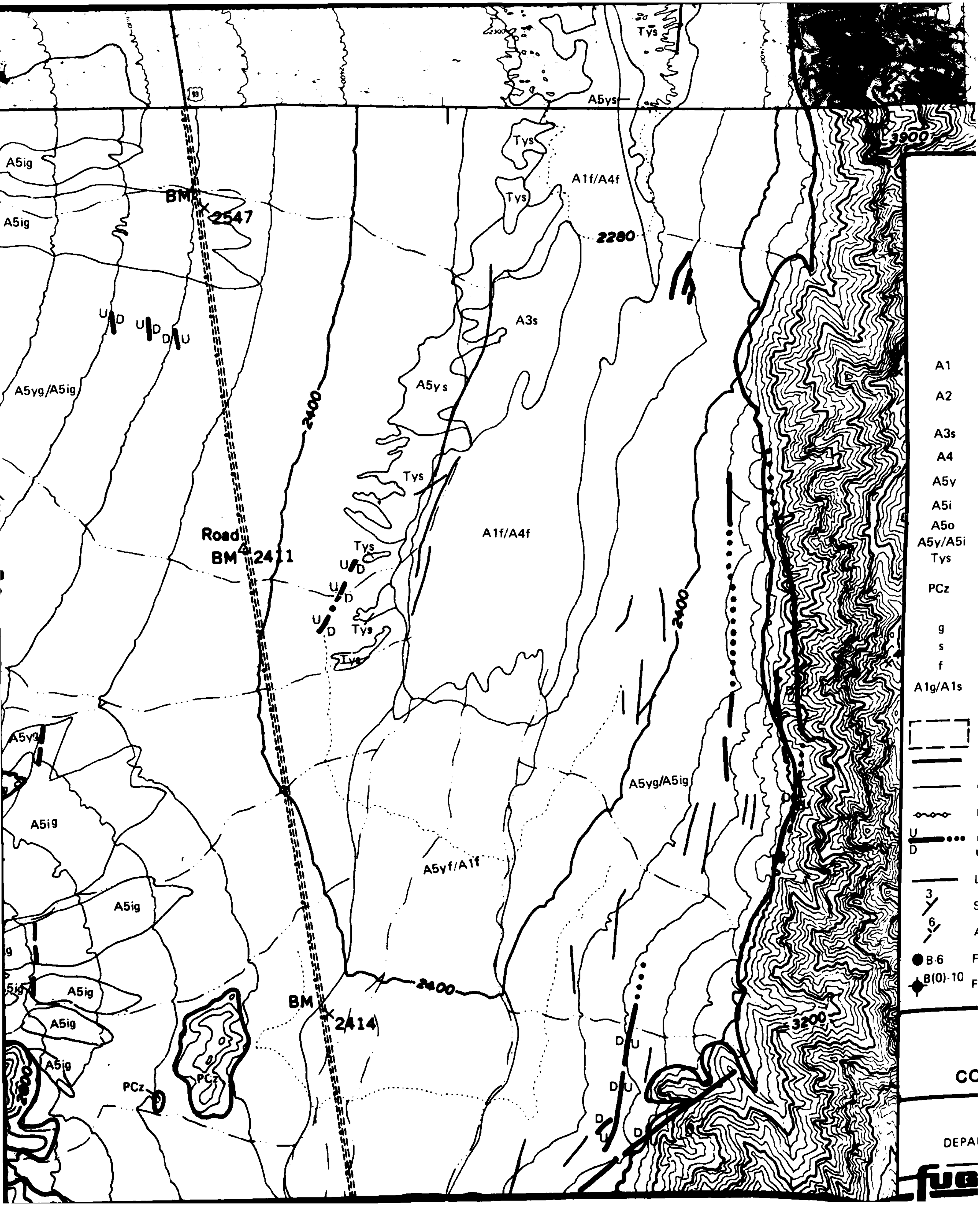
PCz
A1g/A1s
A5ig
A5ig
A5ig
A5yg/A5ig
A5ig/A5yg
18
17
16
A5ig
PROPOSED BASE HOUSING
OPTION 1
PROPOSED MAIN OPERATION
Junction
PCz
PCz
A5ig
A5ig
A5ig
A5yg/A5ig
19
20
21
A5ig
A5ig
A1g/A1s
STATE
A5ig
A5ig
30
29
28
Gravel Pit
BOUNDARY
A5yg
A5ig
A5yg/A5ig
RANGE
A5ig
31
32
33
PCz
PCz
BM 2507
A5yg
ROAD
A5yg/A5ig
INDEFINITE
SAWMILL
PCz
36°45'


PROPOSED MAIN OPERATIONAL BASE
PROPOSED RUNWAY
STATE ROUTE 7
Starvation Flat
Junction
Gravel Pit
ROAD
TRAIL
Pahranagat
A5yg A5ig
A5ig
A5yg/A5ig
A1g/A1s
A5yg/A5ys
A5og
A5yg
Tys
PCz
B-12
B-11
B (0) · 10
D U
2338
2300
2260
2282
2400
2500
2600
BM 2507

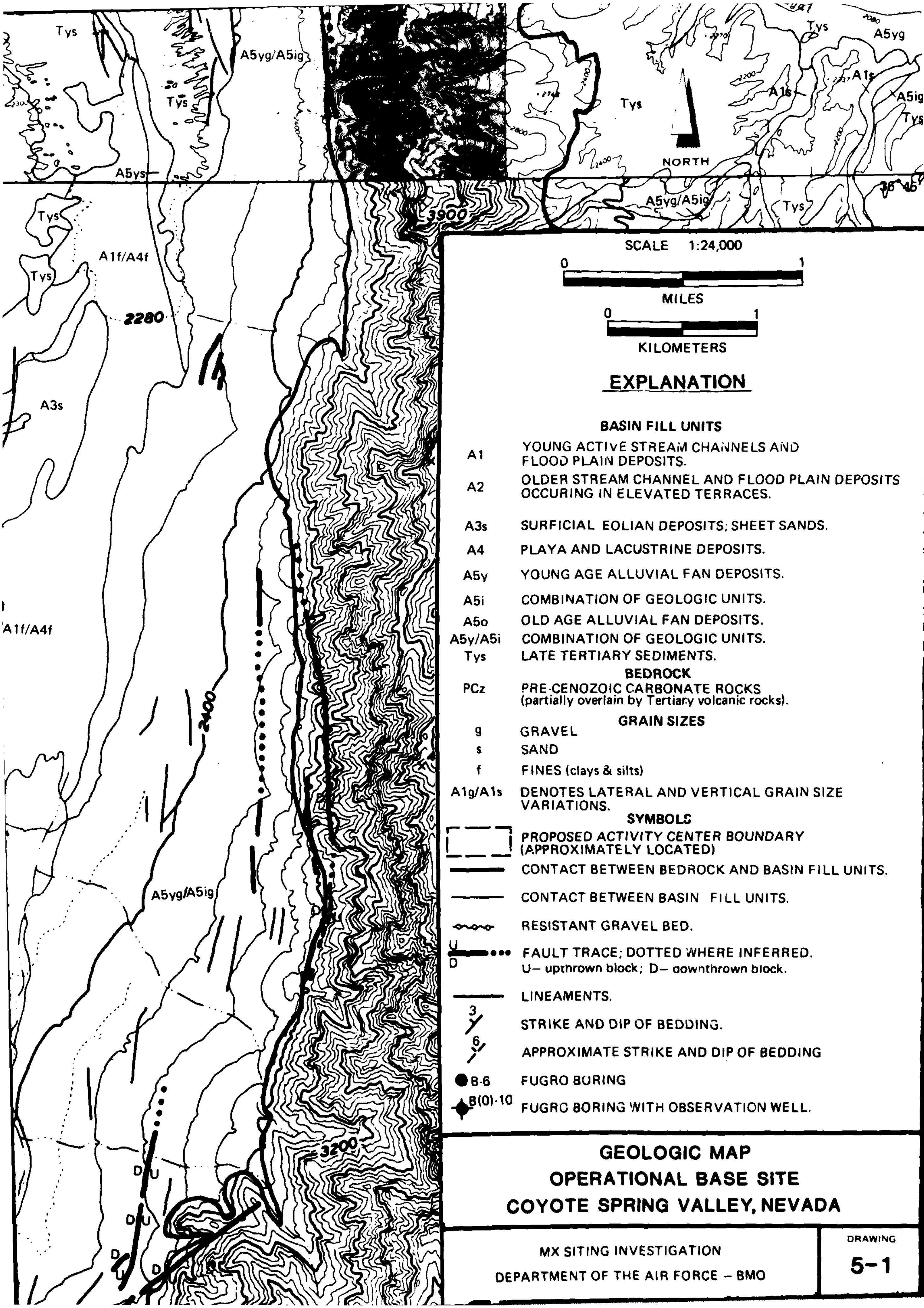

PROPOSED BASE HOUSING
OPTION 2
OLD U.S. HIGHWAY 93
C O Y O T E
S P R I N G
Starvation Flat
B-11
A'
Pahranagat
Wildcat
Wash
JEEP
TRAIL
Dry Well
Borrow Pit
BM 2912
BM 2569
Tys
PCz
A5ig
A5og
A5yg
A1g/A1s
A1s/A1g
A5yg/A5ys
A5ys/A5yg
A1g/A5ig
U
D
11
12
13
14
23
24
25
26
35
36



36°45'
3922
ROAD
SAWMILL
Canyon
Elbow
A1g/A1s
A5yg
PCz
R62 E
R63 E
A1g
A5yg
A5ig
A5yg/A5ig
2800
U
D
BM
2547
A5ig
4124
3337
Road
BM
A5yg
PCz
3600
4053
3644
BOUNDARY
A1g/A1s
115°00'
3670
Central
VABM 4230



Tys
A5ys
2300
93
3900
A5ig
BM
2547
Tys
A1f/A4f
2280
A3s
U D
A5yg/A5ig
A5ys
2400
Tys
Road
BM 2411
A1f/A4f
A5yg
A5yg/A5ig
A5ig
A5yf/A1f
2400
BM
2414
3200
D U
PCz
A1
A2
A3s
A4
A5y
A5i
A5o
A5y/A5i
Tys
PCz
g
s
f
A1g/A1s
B-6
B(0)-10



SCALE 1:24,000

0 — 1 MILES

0 — 1 KILOMETERS

EXPLANATION

BASIN FILL UNITS

A1	YOUNG ACTIVE STREAM CHANNELS AND FLOOD PLAIN DEPOSITS.
A2	OLDER STREAM CHANNEL AND FLOOD PLAIN DEPOSITS OCCURING IN ELEVATED TERRACES.
A3s	SURFICIAL EOLIAN DEPOSITS; SHEET SANDS.
A4	PLAYA AND LACUSTRINE DEPOSITS.
A5y	YOUNG AGE ALLUVIAL FAN DEPOSITS.
A5i	COMBINATION OF GEOLOGIC UNITS.
A5o	OLD AGE ALLUVIAL FAN DEPOSITS.
A5y/A5i	COMBINATION OF GEOLOGIC UNITS.
Tys	LATE TERTIARY SEDIMENTS.

BEDROCK

PCz	PRE-CENOZOIC CARBONATE ROCKS (partially overlain by Tertiary volcanic rocks).

GRAIN SIZES

g	GRAVEL
s	SAND
f	FINES (clays & silts)
A1g/A1s	DENOTES LATERAL AND VERTICAL GRAIN SIZE VARIATIONS.

SYMBOLS

PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

CONTACT BETWEEN BEDROCK AND BASIN FILL UNITS.

CONTACT BETWEEN BASIN FILL UNITS.

RESISTANT GRAVEL BED.

U / D — FAULT TRACE; DOTTED WHERE INFERRED. U– upthrown block; D– downthrown block.

LINEAMENTS.

3 — STRIKE AND DIP OF BEDDING.

6 — APPROXIMATE STRIKE AND DIP OF BEDDING

B-6 — FUGRO BORING

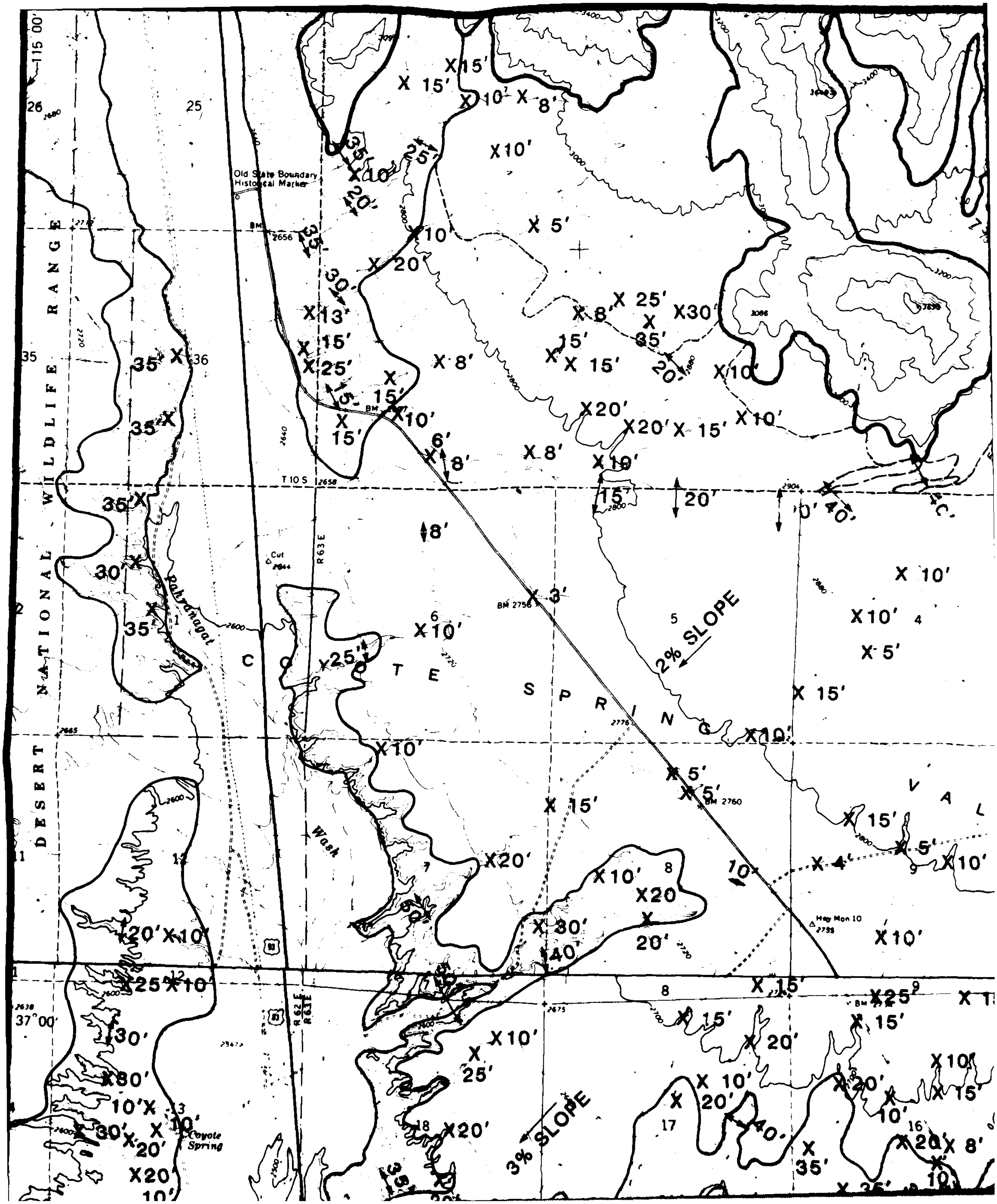
B(0)-10 — FUGRO BORING WITH OBSERVATION WELL.

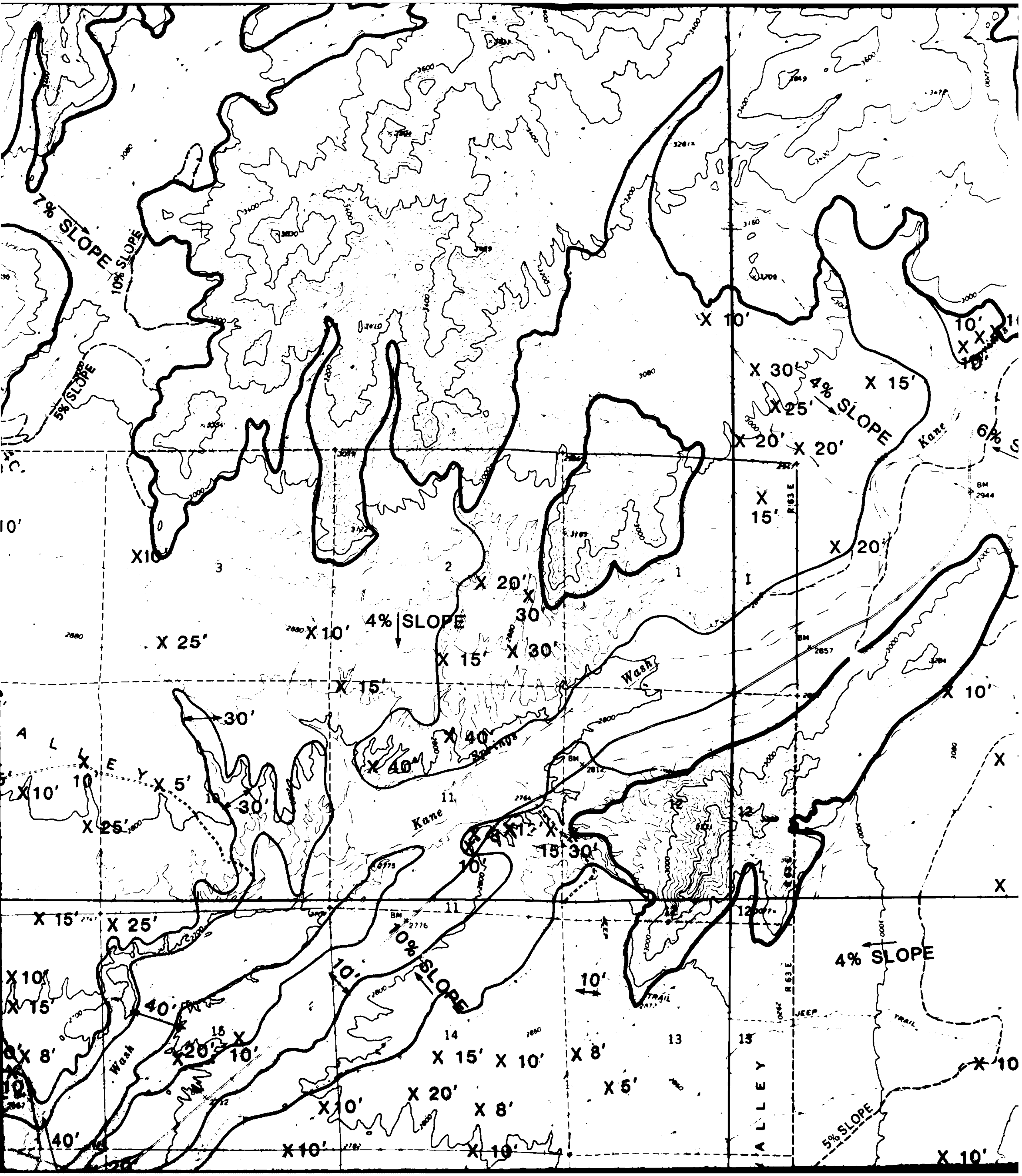
GEOLOGIC MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION

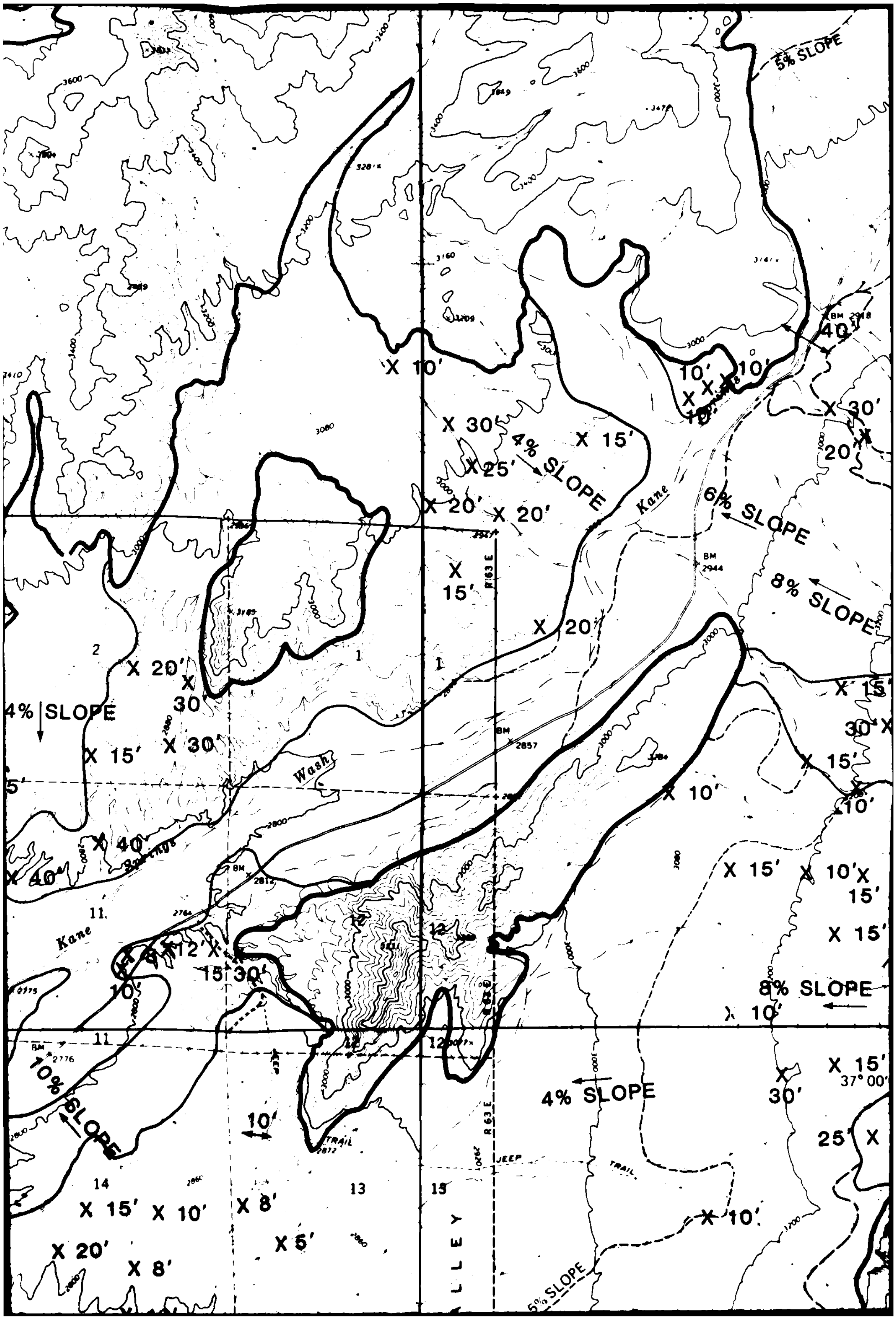
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING 5–1

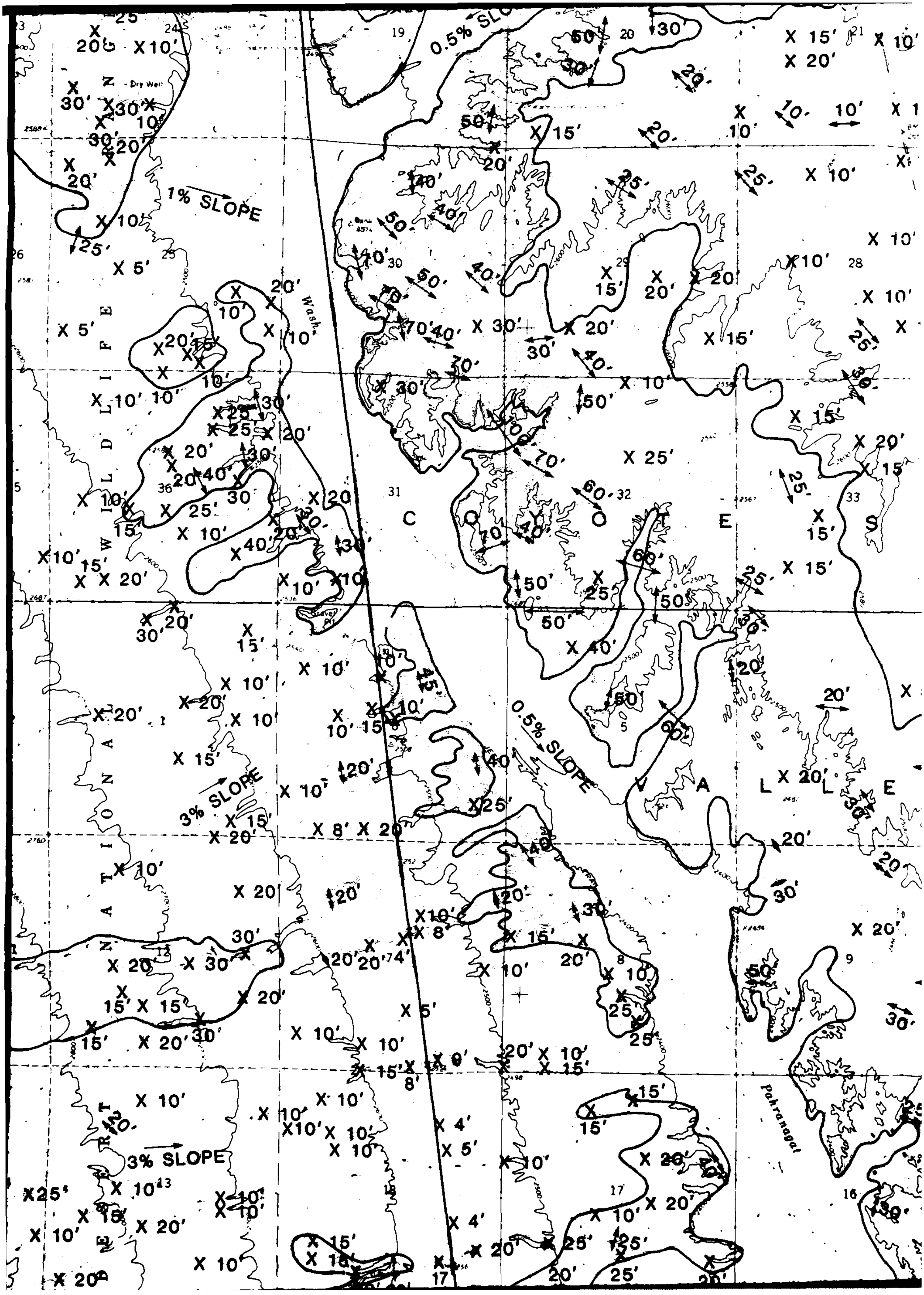

115°00'
DESERT NATIONAL WILDLIFE RANGE
Old State Boundary Historical Marker
COYOTE SPRING
VAL
Pahranagat
Wash
Coyote Spring
2% SLOPE
3% SLOPE
T 10 S
R 63 E
R 62 E
R 63 E
37°00'
Hay Mon 10
BM 2756
BM 2760
Cut

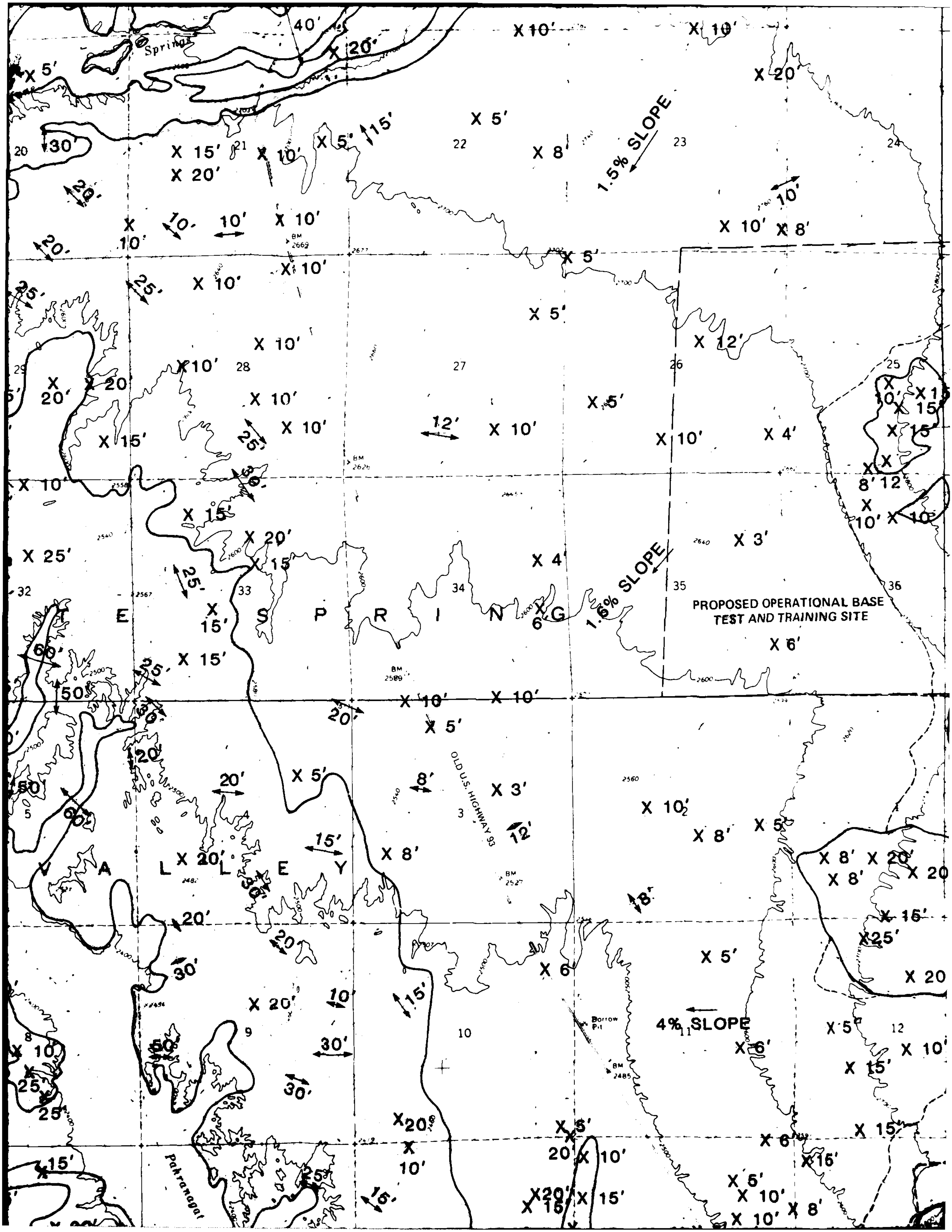


7% SLOPE
10% SLOPE
5% SLOPE
4% SLOPE
4% SLOPE
6% SLOPE
10% SLOPE
4% SLOPE
5% SLOPE
Kane
Kane
Kane
Springs
Wash
Wash
VALLEY
VALLEY
JEEP
TRAIL
TRAIL
R 63 E
BM 2944
BM 2857
BM 2812
BM 2776
X 10'
X 30'
X 15'
X 25'
X 20'
X 20'
X 15'
X 20'
X 20'
X 10'
X 25'
X 15'
X 30'
X 15'
X 40'
X 40'
X 10'
X 5'
X 25'
X 15'
X 25'
X 10'
X 15'
X 8'
X 10'
X 15'
X 10'
X 8'
X 5'
X 10'
X 20'
X 8'
X 10'
X 10'
X 10'
X 10'
X 10'

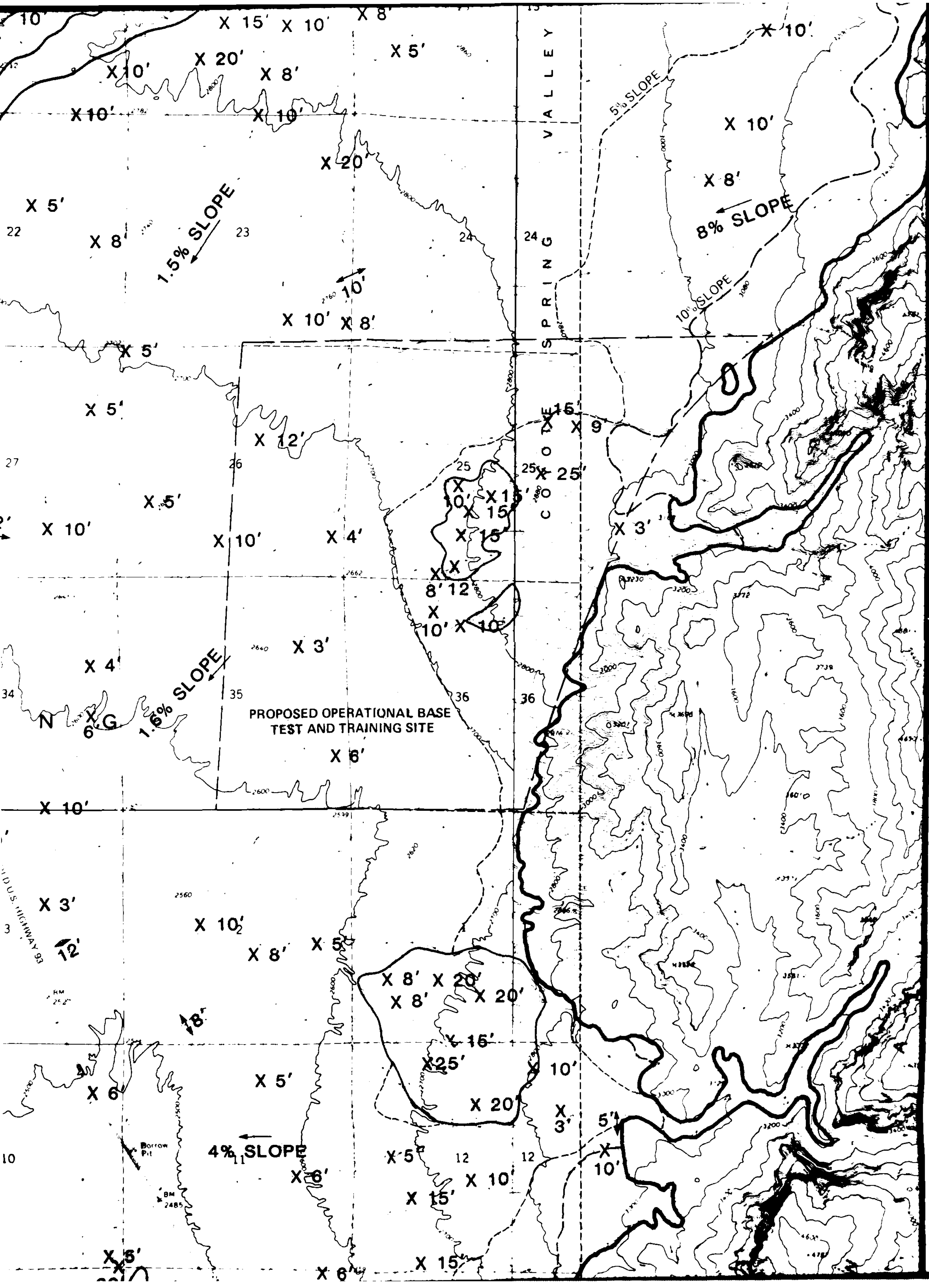


5% SLOPE
X 10'
40'
10'
10'
X 30'
X 30'
4% SLOPE
X 15'
X 25'
X 20'
X 20'
20'
Kane
6% SLOPE
BM 2944
8% SLOPE
X 15'
X 20'
X 20'
X 30
4% SLOPE
X 15'
X 30'
X 15'
30'
BM 2857
Wash
X 15'
X 10'
10'
X 40
Springs
X 40
X 15'
X 10'
15'
X 15'
Kane
12'
15'
30'
10'
8% SLOPE
10'
BM 2776
10% SLOPE
X 15'
37° 00'
4% SLOPE
30'
10'
R 63 E
25' X
TRAIL
JEEP
TRAIL
X 15'
X 10'
X 8'
X 10'
X 5'
X 20'
X 8'
5% SLOPE


1% SLOPE
0.5% SLOPE
0.5% SLOPE
3% SLOPE
3% SLOPE
Dry Well
Wash
Gravel Pit
Pahranagat
C O T E S
A L L E



PROPOSED OPERATIONAL BASE
TEST AND TRAINING SITE
1.5% SLOPE
1.6% SLOPE
4% SLOPE
OLD U.S. HIGHWAY 93
Springs
Borrow Pit
Pahranagat
T E L S P R I N G
V A L L E Y
BM 2669
BM 2626
BM 2589
BM 2527
BM 2485



SPRING VALLEY
COYOTE
PROPOSED OPERATIONAL BASE
TEST AND TRAINING SITE
1.5% SLOPE
1.6% SLOPE
4% SLOPE
5% SLOPE
8% SLOPE
10% SLOPE
U.S. HIGHWAY 93
Borrow Pit
BM 2485

AD-A112 772 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7
MX SITING INVESTIGATION. PRELIMINARY GEOTECHNICAL INVESTIGATION--ETC(U)
DEC 80 F04704-80-C-0006
UNCLASSIFIED FN-TR-43-VOL-1 NL

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END
DATE
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4 82
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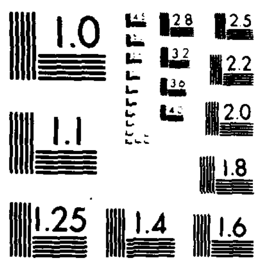
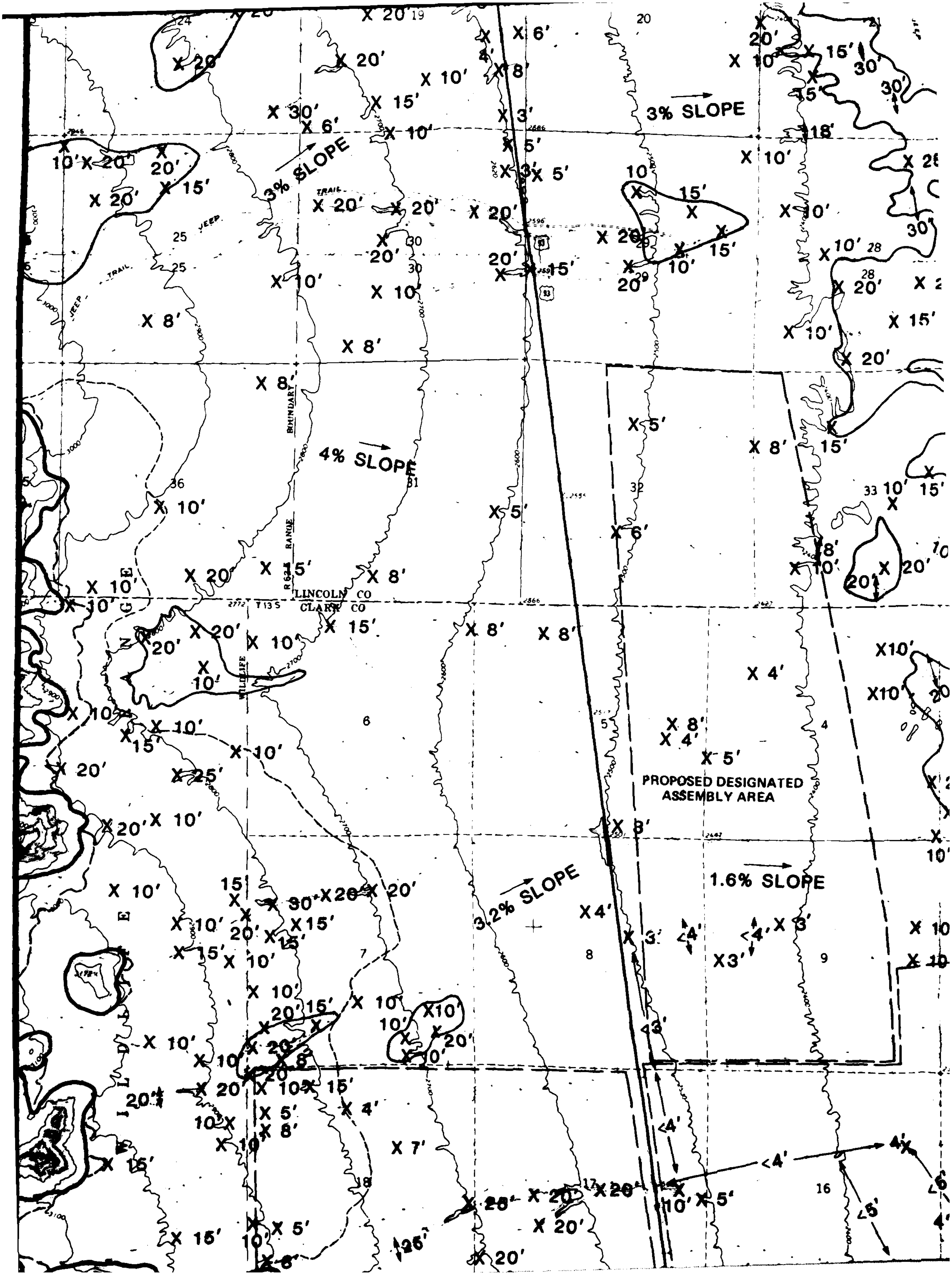
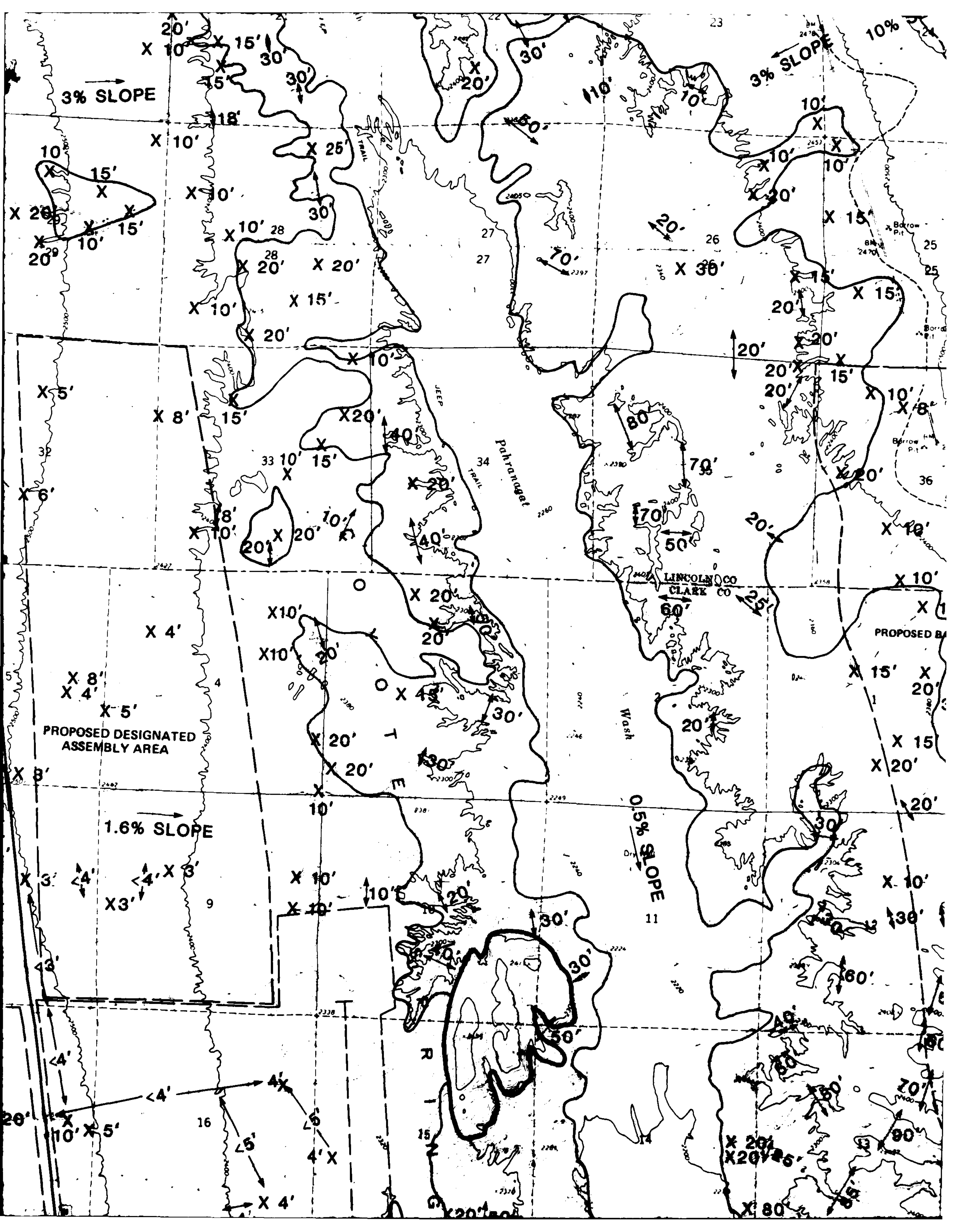


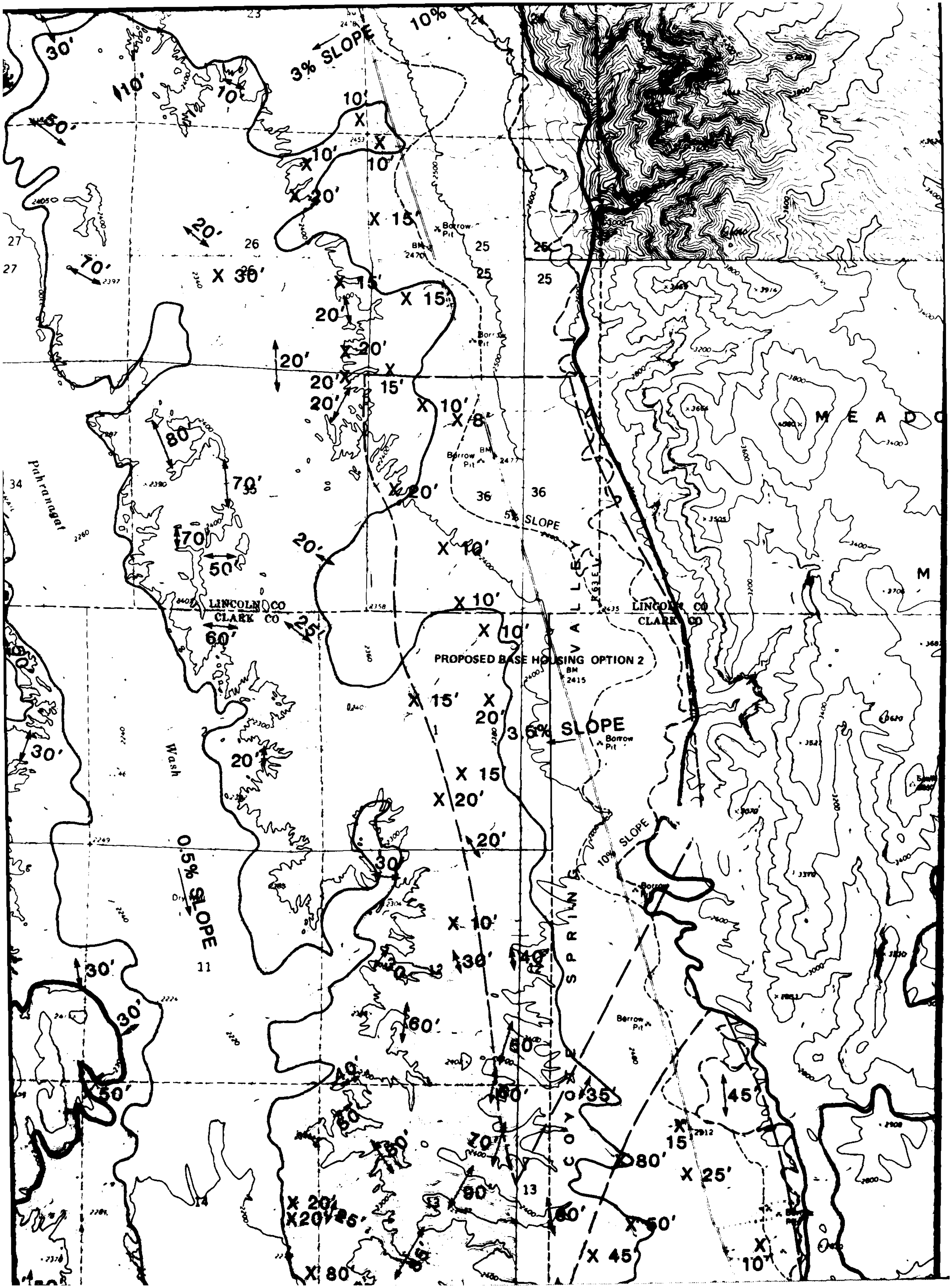
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



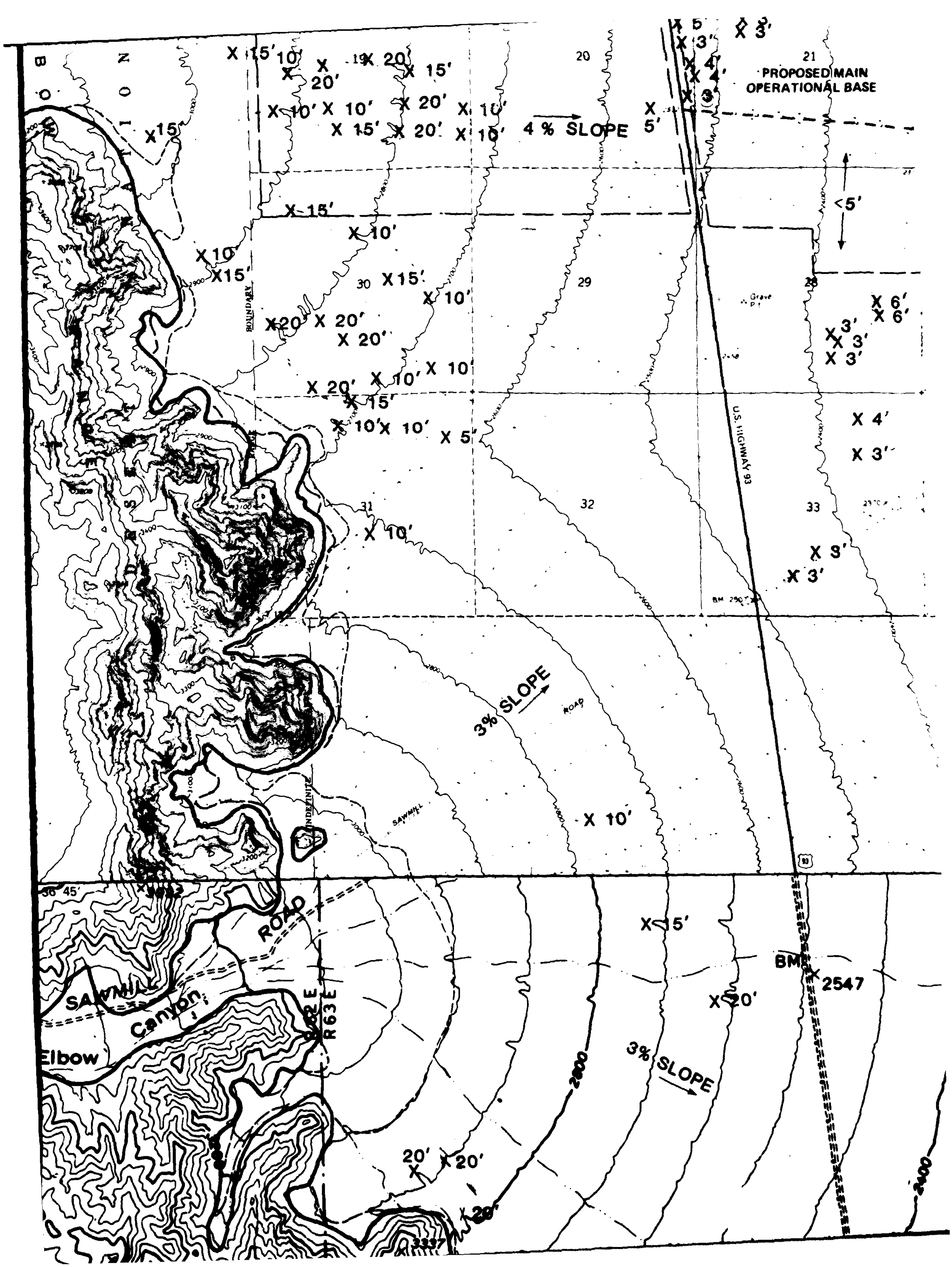
3% SLOPE
3% SLOPE
JEEP TRAIL
4% SLOPE
BOUNDARY
RANGE
R 62 E
LINCOLN CO
CLARK CO
T 13 S
WILDLIFE
PROPOSED DESIGNATED
ASSEMBLY AREA
3.2% SLOPE
1.6% SLOPE



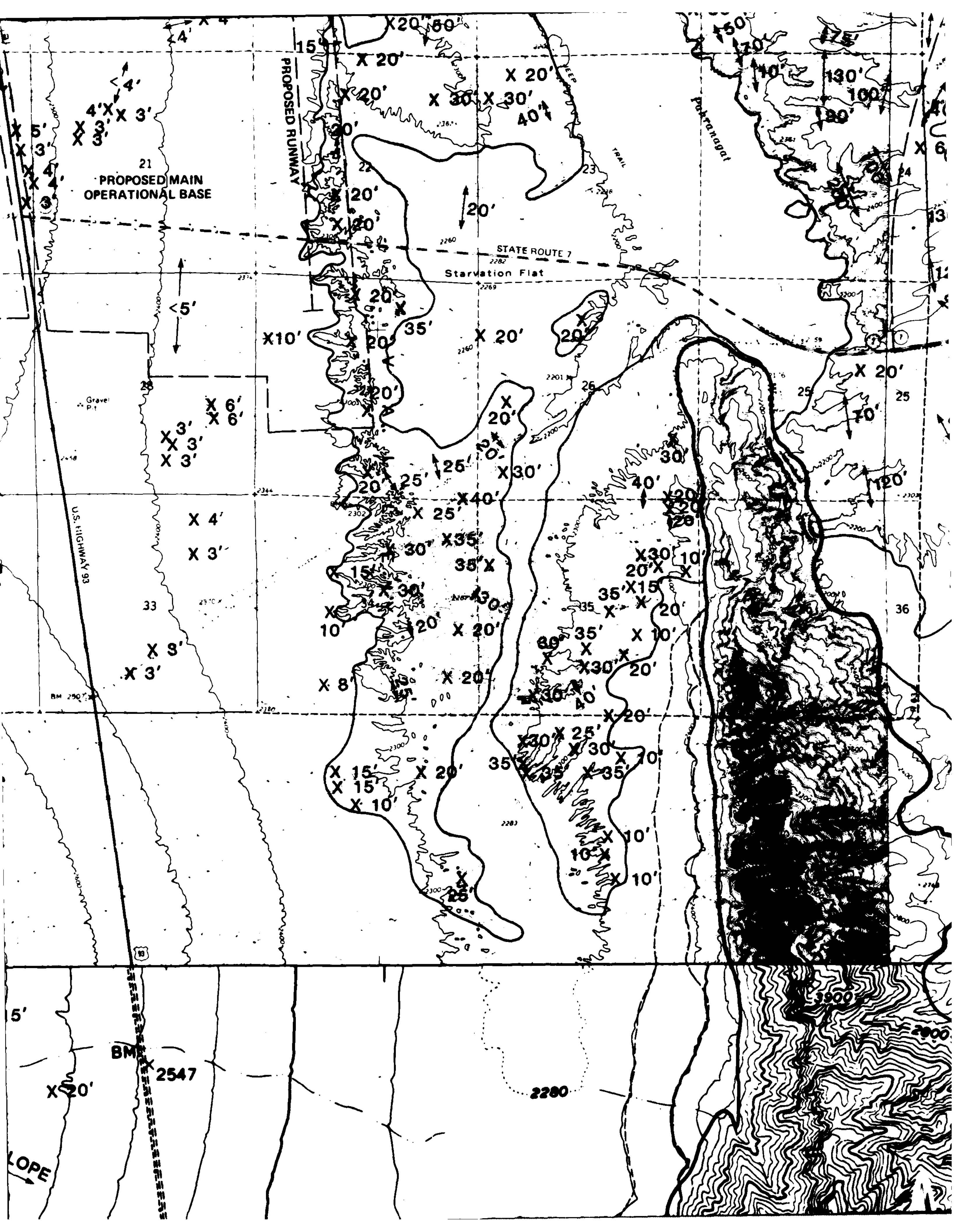
3% SLOPE
3% SLOPE
PROPOSED DESIGNATED
ASSEMBLY AREA
1.6% SLOPE
0.5% SLOPE
Pahranagat
Wash
LINCOLN CO
CLARK CO
JEEP
TRAIL
TRAIL
Borrow Pit



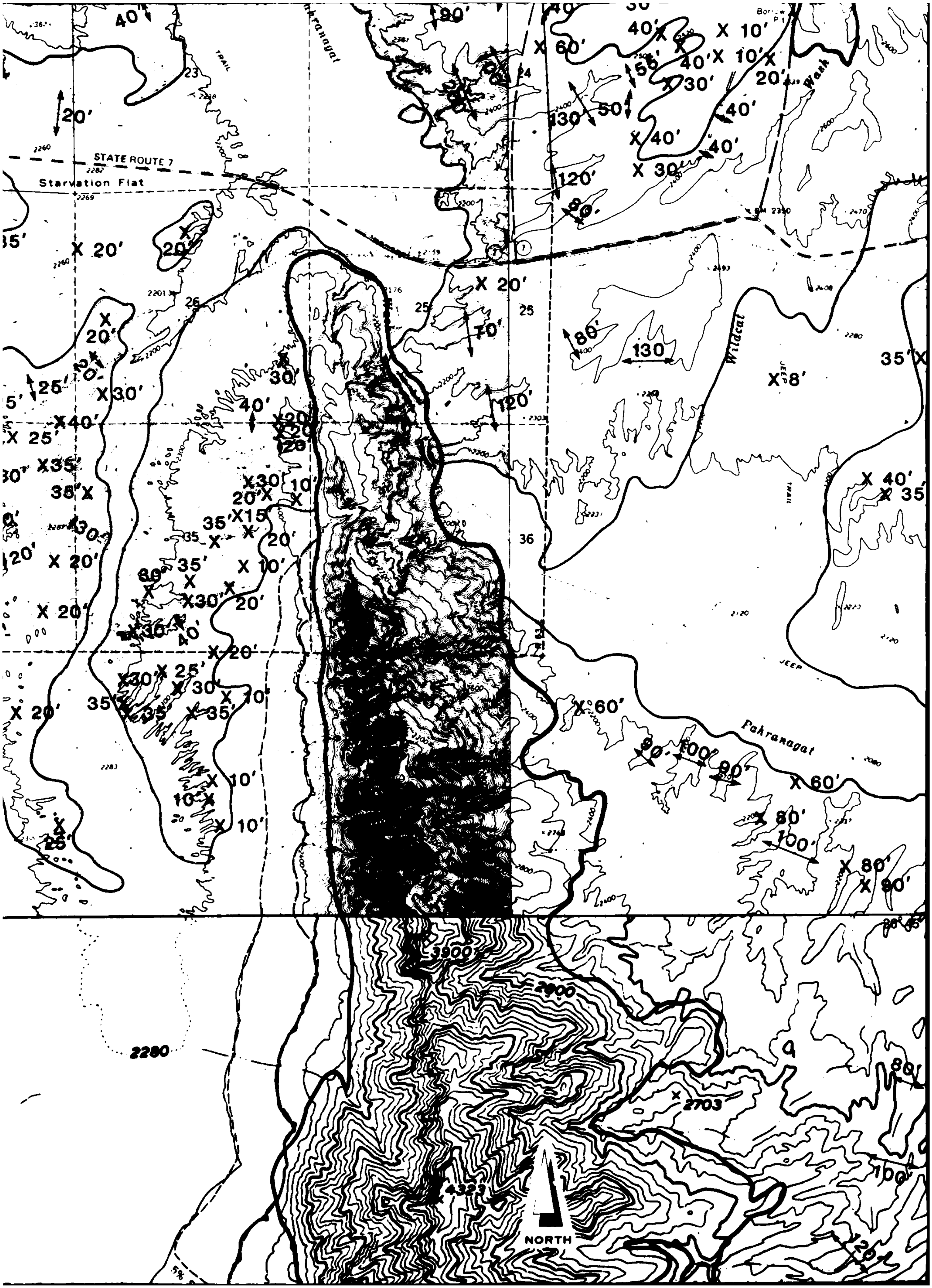
3% SLOPE
10%
5% SLOPE
3.5% SLOPE
0.5% SLOPE
10% SLOPE
PROPOSED BASE HOUSING OPTION 2
LINCOLN CO
CLARK CO
LINCOLN CO
CLARK CO
SPRING VALLEY
Pahranagat
Wash
MEADO
Borrow Pit
BM 2470
BM 2415
R63E

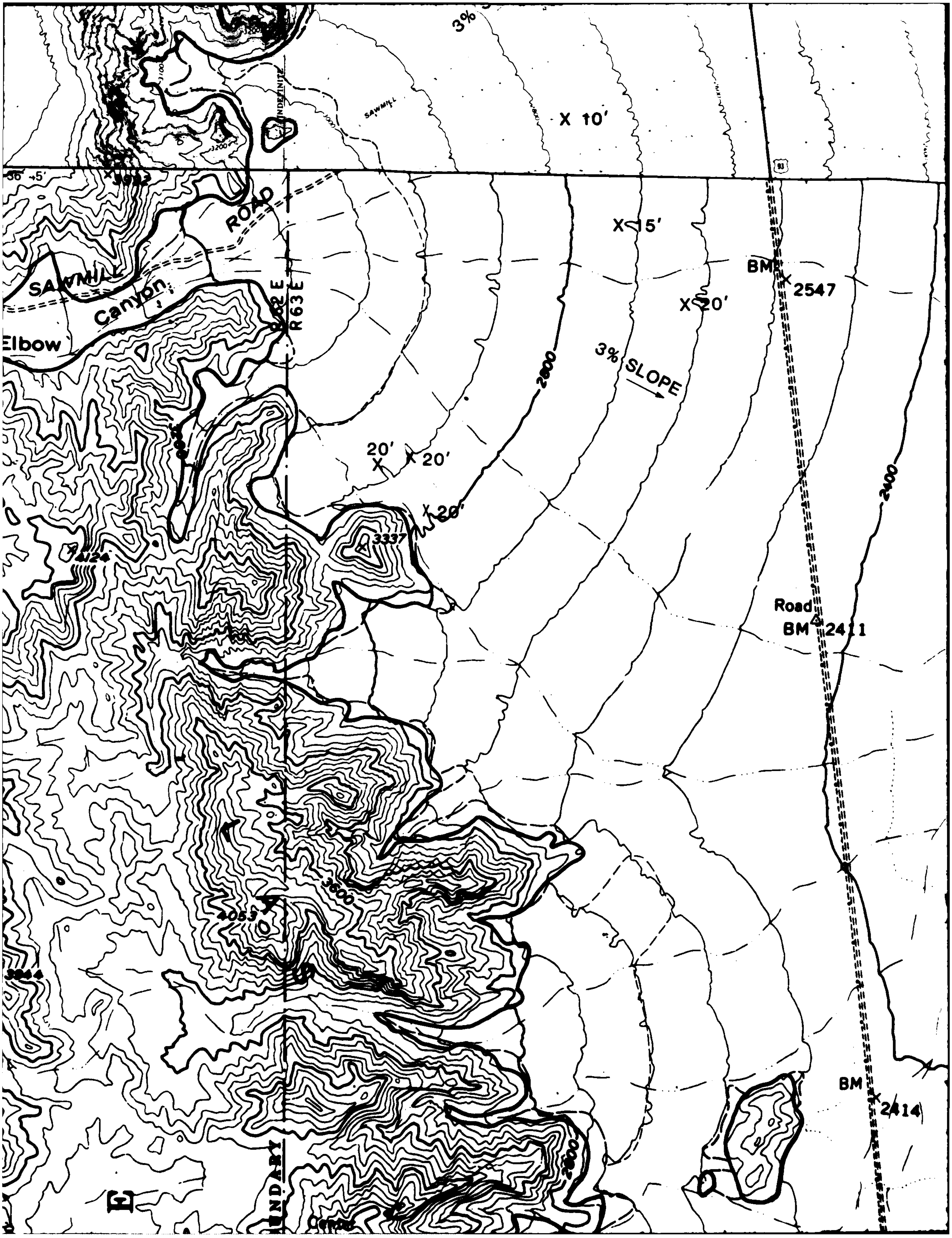


PROPOSED MAIN
OPERATIONAL BASE
4 % SLOPE
<5'
3% SLOPE
U.S. HIGHWAY 93
SAWMILL
ROAD
SAWMILL
Canyon
Elbow
R62E
R63E
BM
2547
3% SLOPE
2600
2400
BOUNDARY

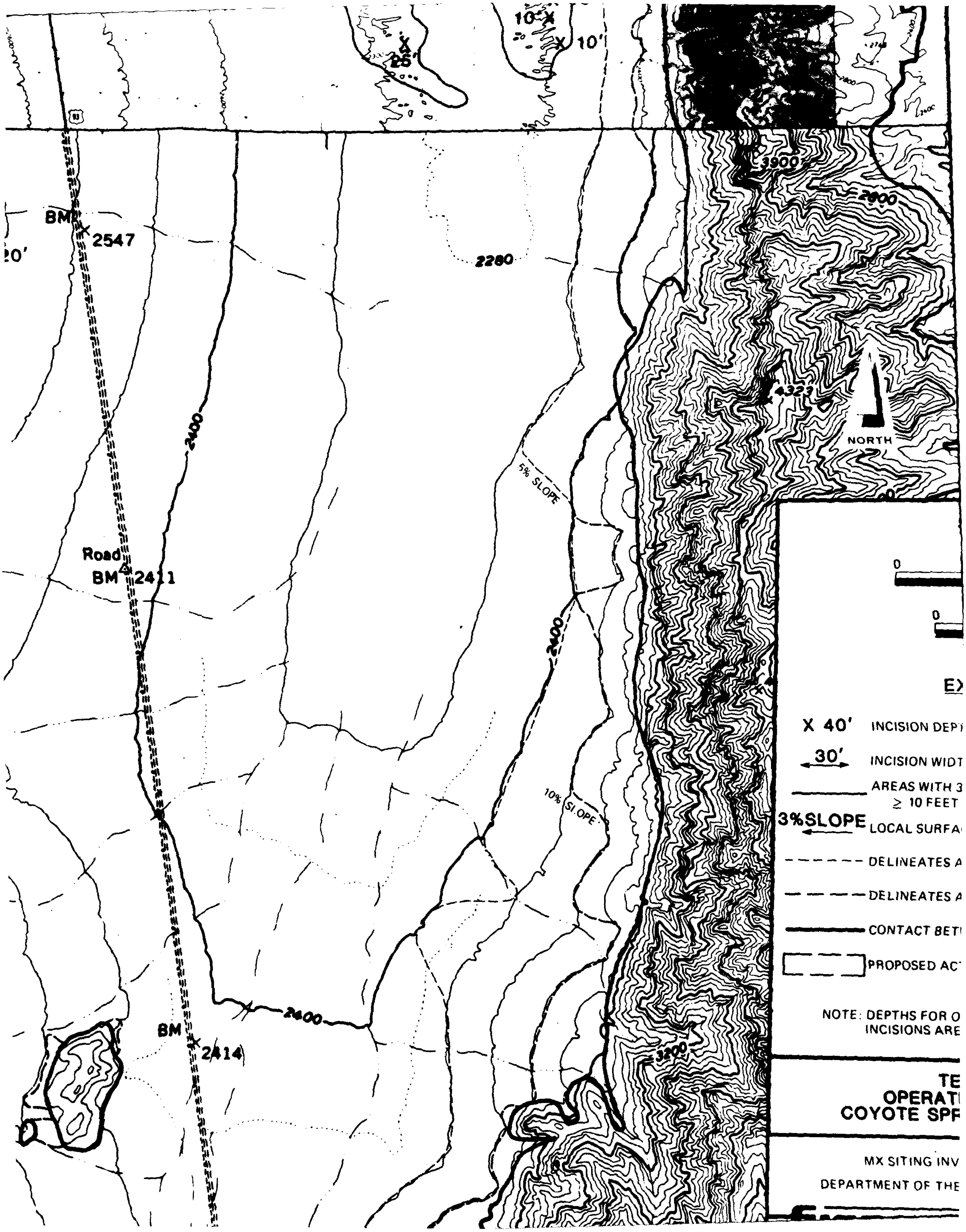


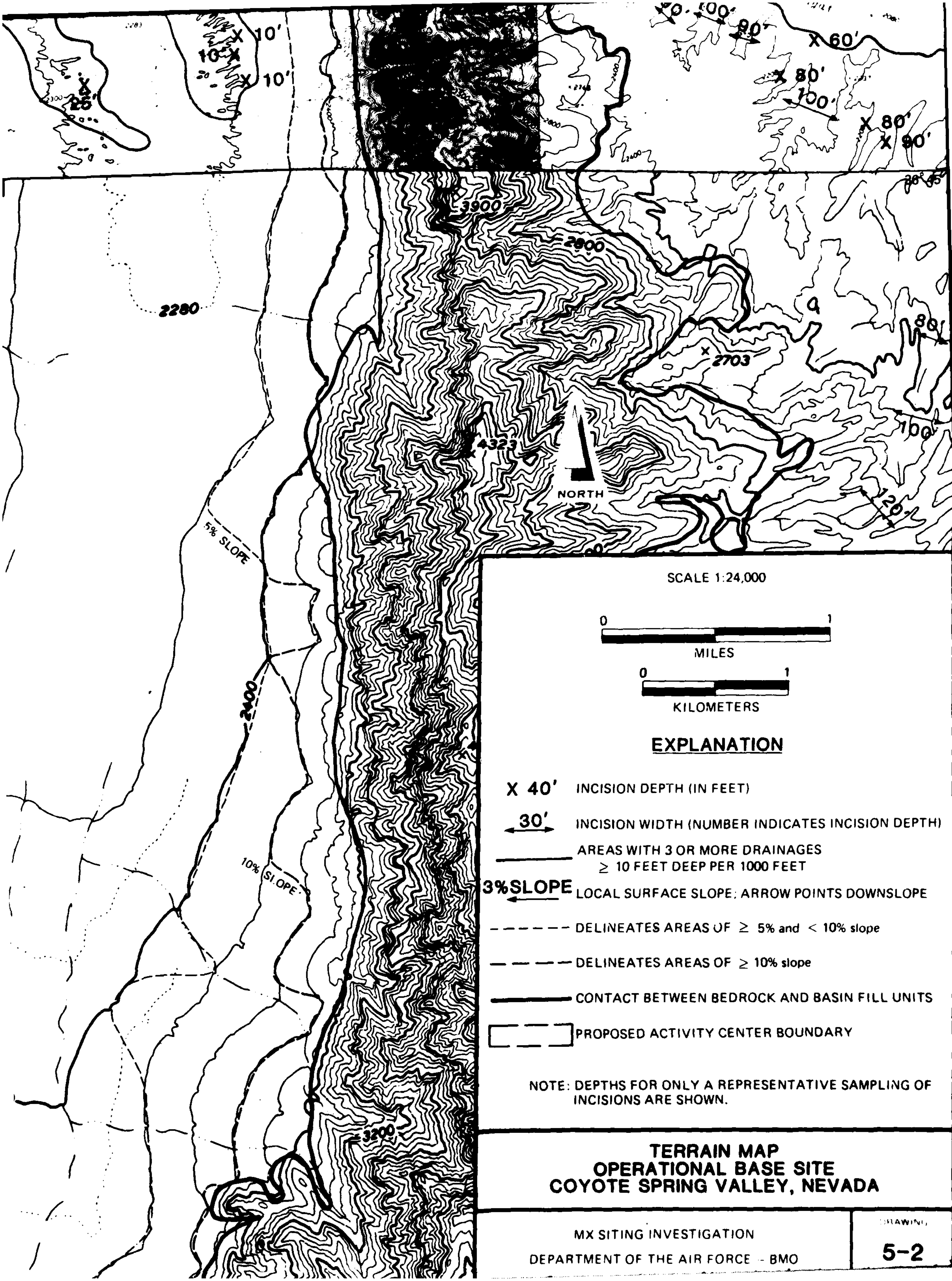
PROPOSED MAIN
OPERATIONAL BASE
PROPOSED RUNWAY
STATE ROUTE 7
Starvation Flat
U.S. HIGHWAY 93
Gravel Pit
TRAIL
JEEP
Pahranagat
BM
2547
2280
3900
LOPE


STATE ROUTE 7
Starvation Flat
Pahranagat
Wildcat
Wash
TRAIL
JEEP
3900
2900
2280
2703
4323
NORTH



3%
SAWMILL
X 10'
ROAD
X 15'
BM
2547
SAWMILL
Canyon
Elbow
R62E
R63E
X 20'
2800
3% SLOPE
20'
20'
20'
3337
4124
Road
BM 2411
2400
3600
4053
BM
2414
2800
BOUNDARY


10'
25'
10'
3900
2900
BM
2547
20'
2280
2400
4323
NORTH
5% SLOPE
Road
BM 2411
2400
10% SLOPE
2400
BM
2414
3200
0
0
EX
X 40' INCISION DEPT
30' INCISION WIDT
AREAS WITH 3
≥ 10 FEET
3%SLOPE LOCAL SURFA
DELINEATES A
DELINEATES A
CONTACT BET
PROPOSED AC
NOTE: DEPTHS FOR O
INCISIONS ARE
TE
OPERAT
COYOTE SPF
MX SITING INV
DEPARTMENT OF THE

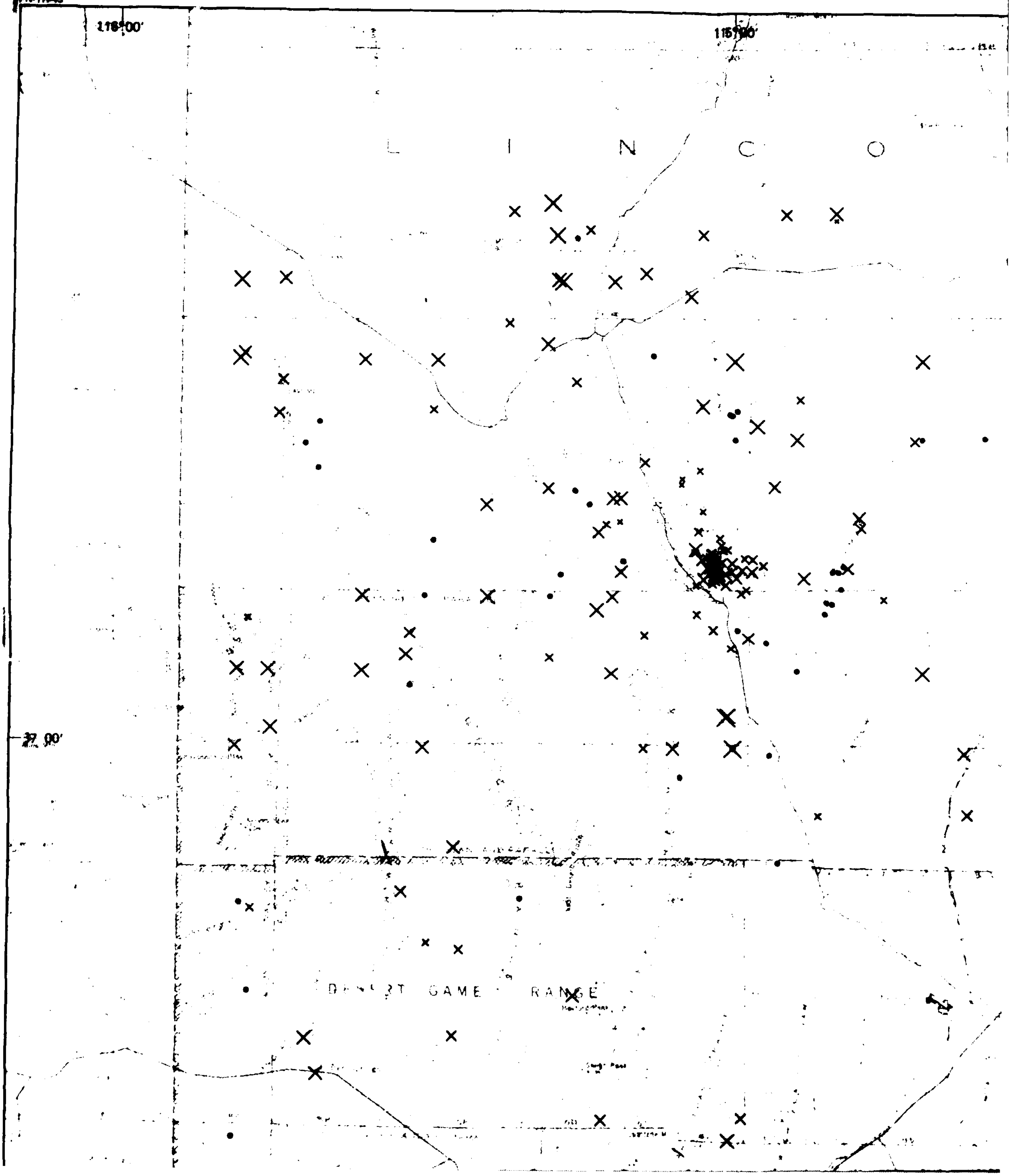


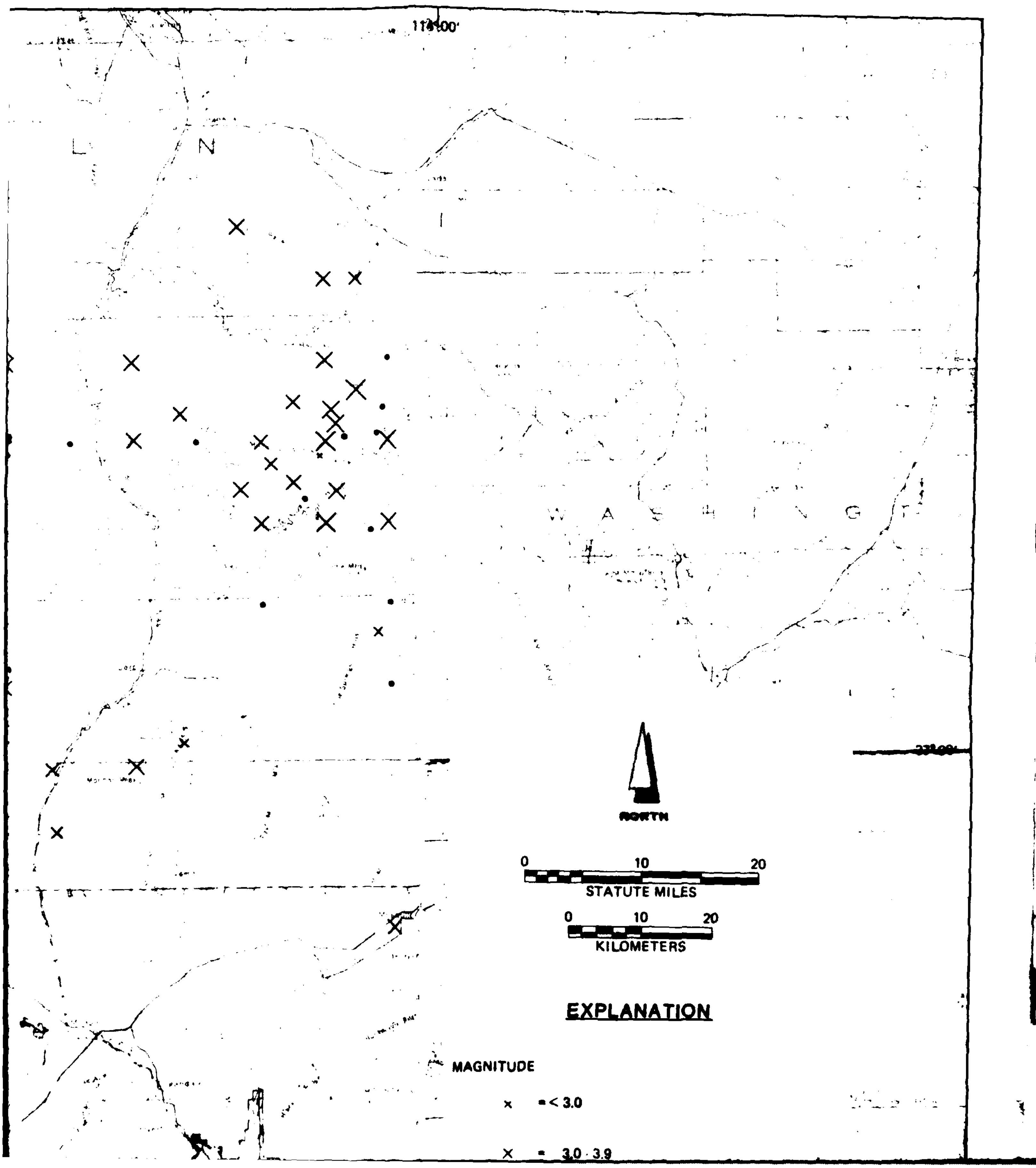
TERRAIN MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

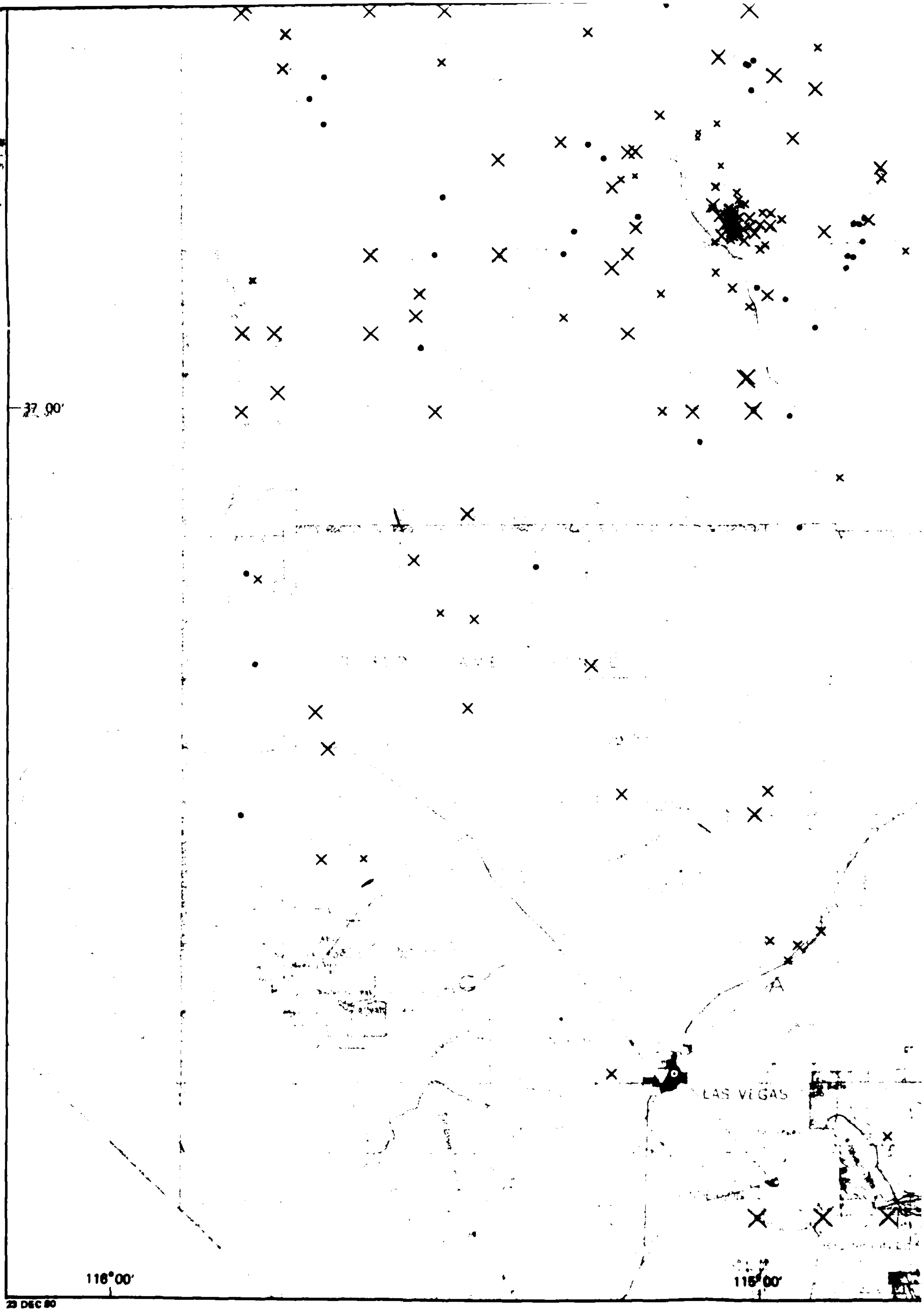
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

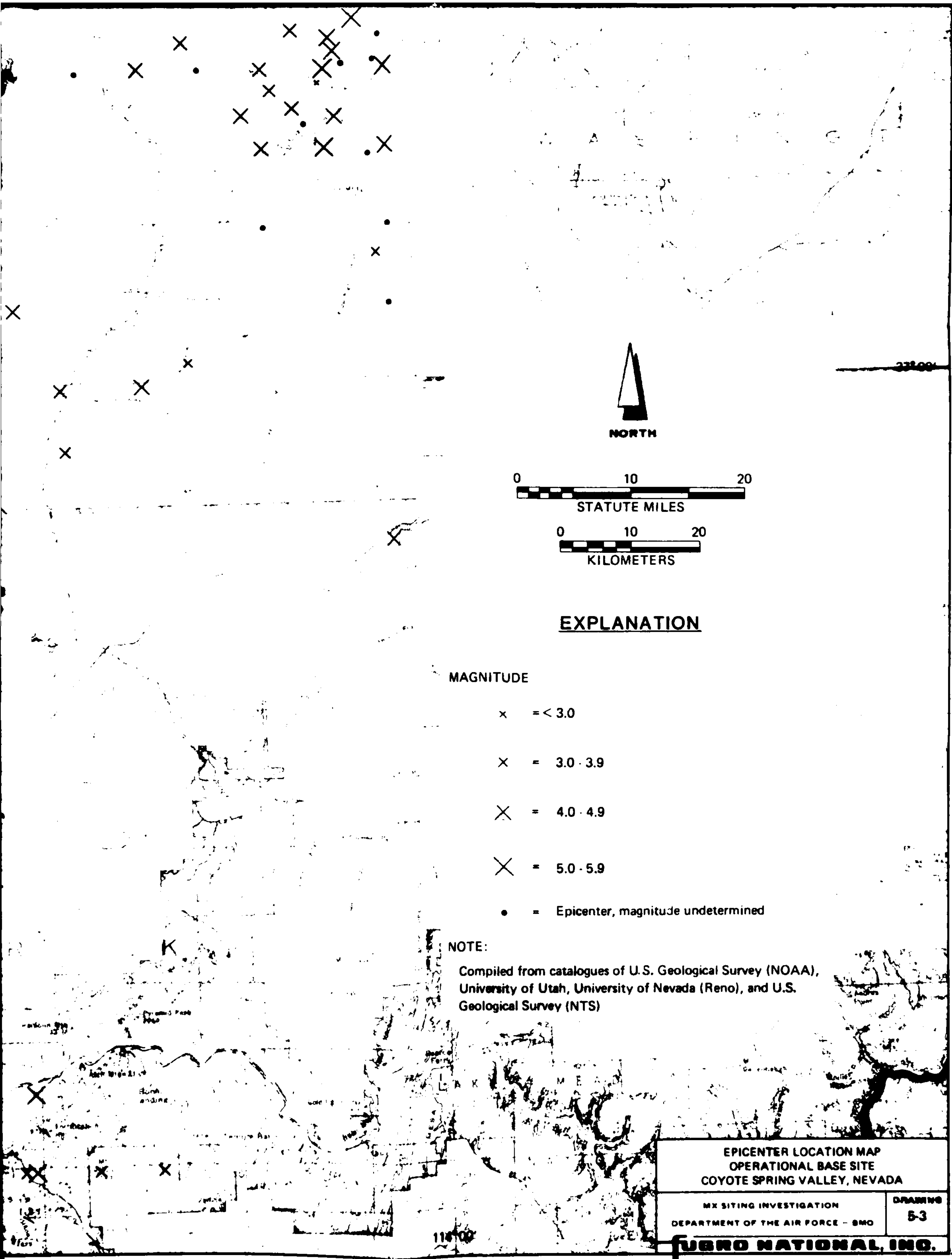
DRAWING
5-2

FN-TR-43




114°00'
W A S H I N G T
NORTH
0 10 20
STATUTE MILES
0 10 20
KILOMETERS
EXPLANATION
MAGNITUDE
x = < 3.0
X = 3.0 - 3.9


37 00'
LAS VEGAS
116°00'
115°00'
23 DEC 80



NORTH
0 10 20
STATUTE MILES
0 10 20
KILOMETERS
EXPLANATION
MAGNITUDE
= < 3.0
= 3.0 - 3.9
= 4.0 - 4.9
= 5.0 - 5.9
= Epicenter, magnitude undetermined
NOTE:
Compiled from catalogues of U.S. Geological Survey (NOAA), University of Utah, University of Nevada (Reno), and U.S. Geological Survey (NTS)
EPICENTER LOCATION MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO
DRAWING
5-3
FUGRO NATIONAL, INC.

6.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6.1 SITE SUITABILITY

Site conditions including depths to rock and water, terrain, flooding, faults, rockfall, and depth to cemented layer for each activity center are summarized in Table 6-1. There do not appear to be any major adverse site conditions, considered within the scope of our study, that would preclude the areas designated from being used for planned facilities.

6.1.1 Depth to Rock

As previously discussed in Section 5.3.3, a remote possibility exists that shallow rock (less than 150 feet) (46 m) would be encountered along the eastern margins of the DAA and MOB. Shallow rock will also be encountered along the eastern margin of the OBTS.

6.1.2 Depth to Water

As previously discussed in Section 5.3.4, the depth to the water table below all of the planned OB activity centers is probably greater than 300 feet (91 m). However, limited quantities of "perched" ground water may exist locally throughout the site areas. If perched water is encountered during construction of the proposed facilities, it may present some construction problems.

6.1.3 Terrain

Terrain conditions in the study area are shown on the terrain map (Drawing 5-2). Terrain conditions for each planned activity

	DESIGNATED ASSEMBLY AREA	OPERATIONAL BASE TEST AND TRAINING SITE	MAIN OPERATIONAL BASE
FAULTS approximate strike surficial geologic units cut by faults	 NS A5ig	 NE A5yg, A5og, Ty	 NS A1g, A1s, Tys
FLOODING* percentage of proposed site within flood hazard area as shown on Drawing- 6-1 .	75%	30%	95%
ROCKFALL HAZARD	NONE	may occur along eastern boundary	none
TERRAIN percent of site excluded (3 or more drainages $\geq$ 10' deep per 1000 feet) percent of site underlain by 5% slope percent of site underlain by 10% slope average incision depth maximum incision depth average surface slope maximum surface slope	 0 0 0 4' 10' 3% 4%	 7% 40% 4% 7' 20' 3% 10%	 7% 0 0 3' 15' 3% 4%
DEPTH TO ROCK ** (high velocity material : >7,000 fps)	150'	rock may occur at depths of less than 150' feet on western boundary along the mountain front.	150'
DEPTH TO CEMENTED LAYER P-1 : Pit number T-2 : Trench number	P-2- refusal at depth of 5 feet. P-3- refusal at depth of 5 feet. P-4- refusal at depth of 5 feet. T-1- refusal at depth of 7 feet.	no excavations	P-5 - refusal at a depth of 6 feet. P-8 - refusal at a depth of 6 feet.
DEPTH TO WATER	>300'	>300'	>300'
PERCENTAGE OF SURFICIAL* GEOLOGIC UNIT UNDERLYING PROPOSED SITE	A1g/A1s 1% A5yg/A5ig 60% A5ig 39%	A1s/A1g 1% A5yg 40% A5ys/A1g 6% A5ys/A5yg 5% A5yg/A5ig 3% A5ig 20% A5og 25%	A5yg/A5ig 84% A1g/A1s 3% A5ig 3% Tys 10%

* SEE DRAWING- 6-1

** High velocity layers may occur intermittently at shallower depths.

2

...TIONAL BASE ...RAINING SITE	MAIN OPERATIONAL BASE	MARSHALLING YARD	BASE HOUSING OPTION I	N & S BASE HOUSING OPTION 2 N	N & S BASE HOUSING OPTION 2 S
...NE A5[illegible], Tv	NS A1g/A1s, Tys	none	none	NS TO NW A1s/A1g, A5vg, A5vg/A5ig, A5og, Tys, PCz	NS TO NE A5vg, A5og, Tys
...0%	95%	100%	75%	40%	0%
... eastern boundary	none	none	may occur along western boundary	may occur along eastern boundary	none
...% ...0% ...% ...7' ...0' ...% ...9%	7% 0 0 3' 15' 3% 4%	7% 0 0 3' 5 2% 2%	0 7% 0 5' 25' 4% 5%	25% 40% 5% 10' 60' 5% 10%	35% 8% 4% 30' 130' 3% badlands topography on western boundary
... at depths of less ...on western boundary ...tain front.	150'	150'	rock may occur at depths of less than 150' feet on western boundary along the mountain front.	rock may occur at depths of less than 150' feet on eastern boundary along the mountain front.	150'
...cavations	P-5 - refusal at a depth of 6 feet. P-8 - refusal at a depth of 6 feet.	no excavations	no excavations	P-22 - refusal at depth of 3 feet. P-23 - refusal at depth of 1 foot. T-11 - refusal at depth of 1½ feet.	P-20 - refusal at depth of 2 feet. P-21 - refusal at depth of 7 feet. T-10 - refusal at depth of 11 feet.
...300'	>300'	>300'	>300'	>300'	>300'
1% 40% 6% 5% 3% 20% 25%	A5vg/A5ig 84% A1g, A1s 3% A5ig 3% Tys 10%	A5vg/A5ig 100%	A1g/A1s 1% A5vg/A5ig 45% A5ig/A5vg 11% A5ig 40% PCz 3%	A1s/A1g 2% A5vg 2% A5vg/A5ig 40% A5ig 6% A5og 45% Tys 2% PCz 3%	A5vg 2% A5og 90% Tys 8%

SUMMARY OF GEOTECHNICAL CONDITIONS
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 6-1

FUGRO NATIONAL, INC.

center are summarized in Table 6-1 and are discussed in the following paragraphs.

Most of the area delineated, because of the incision depth and spacing criteria, occurs as a linear belt about two miles (3 km) wide that trends diagonally through the study area. This area is underlain primarily by "badlands topography." Small portions of areas underlain by A5i and A5y deposits are also excluded. Areas with surface gradients that exceed five percent and ten percent generally occur along the margins of Coyote Spring and Kane Springs valleys and are delineated on the terrain map (Drawing 5-2). Slopes that exceed five percent and ten percent were not delineated in areas of "badlands topography." Local surface gradients in areas of less than five percent slope are also indicated on the terrain map with arrows pointing in the downslope direction.

- Proposed Main Operational Base (MOB) - Most of the proposed MOB is underlain by A5y/A5i deposits except the southeastern margin which is underlain primarily by Tertiary lake sediments. The average surface slope is about three percent easterly, except along the southeastern margin where there is "badlands topography." A 15-foot-(4.5-m) deep incision trends east-west through the northern portion of the site. Aside from this incision, the maximum incision depth is about 10 feet (3 m) with an average depth of about 3 feet (0.9 m). About seven percent of the proposed MOB site is excluded because of adverse terrain. The excluded area is along the southeastern margin of the proposed site where the Tertiary lake sediments occur.

- Proposed Designated Assembly Area (DAA) - The eastern margin of the proposed DAA is underlain by A5i deposits. The remaining area is underlain by A5y/A5i deposits. The surface slope of the proposed activity site is about three percent easterly. The maximum incision depth is approximately 10 feet (3 m) with an average depth of 4 feet (1.2 m). None of the proposed DAA is excluded.

- Proposed Operational Base Test and Training Site (OBTS) - About 20 percent of the proposed OBTS is underlain by A5i deposits, about 30 percent by A5o deposits, and 50 percent by A5y deposits. The A5ig deposits have an average surface slope of about five percent westerly. The maximum incision depth is about 25 feet (7.6 m) with an average depth of 7 feet (2 m). The surface slope where the A5o deposits occur is about two percent southerly. The terrain consists of rolling topography with about 3 to 12 feet (1.0 to 3.6 m) of relief. The surface slope in areas underlain by A5y deposits is about four percent westerly and southerly with a maximum incision depth of about 4 feet (1.2 m) and average depth of about 2 feet (0.6 m).

  About five percent of the proposed OBTS area contains unsuitable terrain based on the incision depth-spacing criteria. The excluded area is in the central portion of the proposed site (Drawing 5-2).

  The extreme northeast corner of the site contains surface slopes greater than ten percent and approximately the eastern third contains surface slopes greater than five percent.

- Proposed Base Housing (BH) - Option 1 - The proposed base housing area (Option 1) is underlain by A5i and A5y/A5i deposits. The A5i surfaces slope easterly at about four percent. The maximum incision depth is about 25 feet (7.6 m) with an average depth of about 10 feet (3 m). Areas underlain by A5y/A5i deposits are generally rugged and have surfaces that slope easterly at about four percent. The maximum incision depth is about 8 feet (2.4 m) with an average depth of about 3 feet (0.9 m).

  Very steep easterly facing bedrock slopes occur along the western margin of the proposed BH site where pre-Cenozoic limestone and dolomite outcrop.

- Proposed Base Housing (BH) - Option 2 - Most of the western portion of the proposed BH (Option 2) is underlain by A5o deposits. The A5o surfaces slope westerly at about two percent. The maximum incision depth in this area is 40 feet (12.2 m) with an average depth of about 20 feet (6.1 m). The east central and northeastern portion of the proposed site is underlain by A5y/A5i deposits which have a surface slope of about four percent westerly. The maximum incision depth is about 45 feet (13.7 m) with an average depth of about 5 feet (1.5 m).

6.1.4 Geologic Hazards

Discussions and conclusions pertaining to flooding, faults and seismic conditions, rockfall, and subsidence are presented in the following paragraphs.

6.1.4.1 Flooding

Major flooding within the site area would usually be confined to the incised floodplains of Pahranagat and Kane Springs washes and their major tributaries. However, it seems unlikely that enough water can accumulate at one time to fill Pahranagat or Kane Springs washes to the point that they would overflow the existing floodplain channels. There is no indication that this has occurred in the recent past.

Flooding on the A5y fans would occur as either stream floods or sheet floods. Stream floods would occur when water and detrital material emerge from the mountain canyons in sufficient quantities to flow down the fan surface, but not in sufficient quantities to overflow the existing channels. The water would essentially remain confined to definite channels on the fan surface. The linear concentrations of cobbles and boulders in many of the A5yg channels suggest that considerable amounts of water must flow down these channels during periods of heavy rainfall. Sheet floods are likely to occur when exceedingly large amounts of water and detritus emerge from a mountain canyon and overflow existing channels, spreading out over broad areas of the fan surface. Sheet floods probably occur only at intervals of several years or longer.

Flooding in areas where A5i and A5o alluvial fan deposits occur would be minimal and primarily restricted to the incisions which cut these units. Although some of these incisions contain linear accumulations of cobbles and boulders, there is no evidence of recent torrential flooding in most of the incisions, which receive only local runoff.

Incision within the lake sediments toward the southern end of the site area are relatively deep and narrow. During a heavy rainfall, some of them may be subject to torrential flooding, but such flooding would probably be restricted to the channels themselves and would abate once the water reaches the relatively broad expanse of Pahranagat and Kane Springs washes.

It appears that within the general area of this OB site the potential for major flooding is low due to the small catchment areas of Coyote and Kane Springs valleys as well as the adjoining Meadow Valley. However, considerable amounts of runoff should be expected in areas of the A5y fan drainages and channels in the central portions of the valleys. The caliche layer on most of the valley surface reduces infiltration and results in higher surface runoff, thus increasing the potential for flash flooding in these areas, some of which are far from the mountain fronts.

A seemingly viable method for protecting roads and facilities from flooding would be diversion dikes. It appears that this method has been used successfully to protect "old" U. S. 93 from flooding. The dikes along the old highway are composed of locally derived cobbles and boulders, are 2 to 3 feet (0.6 to 0.9 m) high and about 3 or 4 feet (0.9 or 1.2 m) wide. They are used to divert drainage to widely spaced culverts that pass under the old highway. An alternative method for protecting roads and facilities from flood hazards would be to elevate the roads above ground level and to use elevated building pads.

6.1.4.2 Faults and Seismic Conditions

For seismic hazards analysis, faults are normally considered active if they are found to displace Holocene or very young Quaternary deposits. For this study, the mapped basin faults within and near the OB are considered potentially active pending further study.

Some of the basin faults and photo lineaments in the study area have displaced surfaces as young as 200,000 years of age. This suggests that faulting has occurred within the last several thousand to as much as 200,000 years, though no Holocene age (<10,000 years ago) sediments were documented to be displaced. For this level of investigation a question remains as to the potential for future fault displacement on those faults identified in the study area. For subsequent engineering planning, fault traces and photo lineaments or projections of these features should be avoided with regard to locating structures. Structure setbacks from fault or lineament traces of several tens to a few hundreds of feet should be considered. If these faults are eventually found to be active (e.g., having moved in the last 10,000 years) consideration should be given to seismic design criteria such as setback from the fault traces and potential levels of shaking.

An important concern is the Kane Springs fault which has a mapped length of about 30 miles (48 km) and trends toward the

OB area. By way of a hypothetical example, if one-half the length of the Kane Springs fault were to move, horizontal ground accelerations at the OB would likely exceed UBC standards (Zone III).

Alternatively if a 6.1 magnitude earthquake similar to the 1965 event discussed in Section 5.5.2 were to occur within five miles (8 km.) of the OB, accelerations approaching 0.4 g are possible. These examples do indicate that further detailed studies need to be performed to develop seismic design criteria for the OB structures.

6.1.4.3 Rockfall

The potential for rockfall hazard appears to be greatest along the eastern margin of Coyote Spring Valley due to the high relief along the steep mountain front. As previously discussed in Section 5.2.1, large near-vertical joints occur along the mountain front. Some of these joints appeared to be several feet wide and several tens of feet long. The possibility exists that during a seismic event, large fragments or rock could break away at these joints and land along the base of the mountain front.

Mountain fronts along Kane Springs Valley and along the western side of Coyote Spring Valley are not likely to present a rockfall hazard. No evidence of rockfalls having occurred along these mountain fronts was observed.

6.1.4.4 Subsidence

As previously discussed in Section 5.5.2, several large north-south trending "joints" or "cracks" trend through the OBTS, BH, (Options 1 and 2), and the DAA. Some of them may be fault related, whereas others may be the results of subsidence due to differential settlement, as suggested by Ealey (1963).

It should be noted that none of the cracks observed in the field show any evidence of recent movement or of having recently formed. If they are the result of differential settlement as suggested, it is likely that the processes that formed them are no longer active and the potential for large-scale settlement problems in the site area is remote. However, since these cracks do present a zone of weakness, the possibility of renewed movement on them during a seismic event should not be ruled out. No structures should be placed across these features.

6.2 FOUNDATION CONSIDERATIONS

In this section, geotechnical properties of the subsurface soils in the activity centers, and foundation recommendations for the structures are discussed.

6.2.1 Geotechnical Properties of Subsurface Soils

The surficial soils to depths ranging from 8 to 24 inches (20 to 61 cm) typically consist of loose cobbles and sand. The surficial soils are underlain by alluvial gravels to a depth of approximately 40 to 60 feet (12.2 to 18.3 m). The gravel is underlain by sand and silt of the lake deposits. The geotechnical properties of these soils are as follows:

- Gravel (GP, GM): The gravel, as explained in Section 5.3, is poorly graded with varying amounts of sand and fines. The gravel has variable and randomly distributed caliche cementation. Its consistency ranges from dense to very dense below 2 feet (0.6 m). Sand lenses are present in the gravel deposit. As evident from the results of the

Standard Penetration Test (SPT) and the Cone Penetrometer Test (CPT), the shear strength of the gravel deposit is high. The compressibility of the gravel will be low; however, the strength and compressibility of the gravelly soils is nonuniform due to the following reasons:

- There is a large variation and combination in the gradation of soil particles. When the soils are clast-supported, i.e., if the gravel-size aggregates are in contact or interlocking with each other, they will have a higher shear strength. However, when the soils are matrix-supported (predominantly by sand and silt), their shear strength will be lower.
- The different stages of cementation have sporadic distribution.
- Cracks and loose lenses or layers, as observed in exposures in incision walls, may occur throughout the gravelly soils.

o <u>Sand (SP, SM) and Silt (ML, CL-ML)</u>: The sand as previously described (Section 5.3), is fine to coarse and is poorly graded. It is dense to very dense and occasionally has cemented zones. For the soil samples tested, the angle of internal friction Ø of the sand ranges from 28^{o} to 44^{o} at natural moisture contents and from 32^{o} to 39^{o} when soaked; correspondingly, the apparent cohesion (c) of the sand has ranges of 0.4 to 2.1 ksf (19.2 to 100.5 kN/m^2) at natural moisture contents and 0.2 to 2.4 ksf (9.6 to 114.9 kN/m^2) in the soaked condition. The unconfined compressive strength of the sand containing a significant amount of fines ranges from 1.8 to 3.8 ksf (86.2 to 181.9 kN/m^2).

The silt is hard and nonplastic. For the soil samples tested, the range of the angle of internal friction Ø for the silt is between 31^{o} and 34^{o} at natural moisture contents and between 24^{o} and 29^{o} when soaked; the cohesion (c) of the silt ranges from 1.8 to 3.2 ksf (86.2 to 153.2 kN/m^2) at natural moisture contents and from 1.6 to 3.2 ksf (76.6 to 153.2 kN/m^2) in the soaked condition. The unconfined compressive strength of the silt is between 0.6 and 8.5 ksf (28.7 and 407.0 kN/m^2). As indicated by the consolidation tests, most of the sand and silt have medium compressibility.

6.2.2 Foundation Recommendations

In order to provide preliminary foundation recommendations for the various facilities in the proposed operational base, all the structures are grouped into three categories according to their anticipated column loads as follows:

- Structures with light column loads (less than 50 kips) (23 tonnes) - Structures with one to two stories
- Structures with medium column loads (50 to 200 kips) (23 to 91 tonnes) - Structures with more than two stories, or light structures with large spans between columns
- Structures with heavy column loads (greater than 200 kips) (91 tonnes) - All Structures with more than two stories, warehouses, and other heavy structures

The subsurface conditions in the MOB, DAA, and BH as revealed by the borings, trenches, and test pits are shown in soil profiles (Figures 6-1 and 6-2). Since the gravelly alluvial fan deposits have a minimum thickness of 60 feet (18.3 m), all structures will be founded in the gravel.

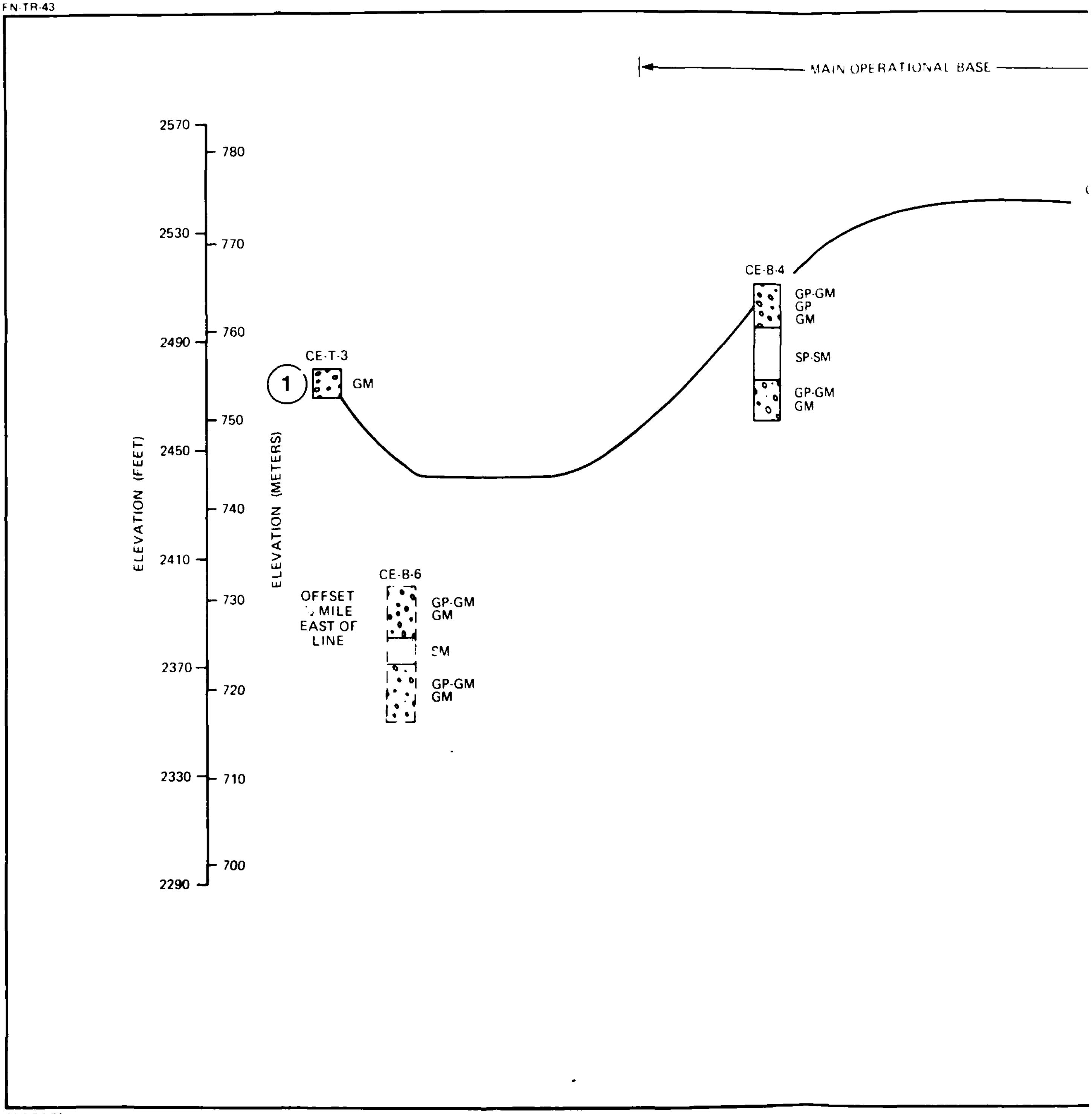
- Columns and Walls: Shallow spread, combined, or continuous footings will be suitable for the foundations of most buildings having the lowest floors at grade. Because of the loose surficial soil, a minimum foundation depth of 1 to 2 feet (0.3 to 0.6 m) below final grade is recommended for the structures with light column loads. Structures with medium and heavy column loads can be adequately founded at minimum depths of 2 to 5 feet (0.6 to 1.5 m) below final grade. The recommended net allowable bearing pressures for the structures are as follows:

Column Load	Minimum Foundation Depth Below Final Grade, feet (meters)	Net Allowable Bearing Pressure, ksf (kN/m2)
Light	1 to 2 (0.3 to 0.6)	2 to 6 (96 to 287)
Medium	2 to 3 (0.6 to 0.9)	5 to 8 (239 to 383)
Heavy	3 to 5 (0.9 to 1.5)	7 to 10 (335 to 479)

The wide range in the bearing pressure is due to the heterogeneity of the gravelly soil.

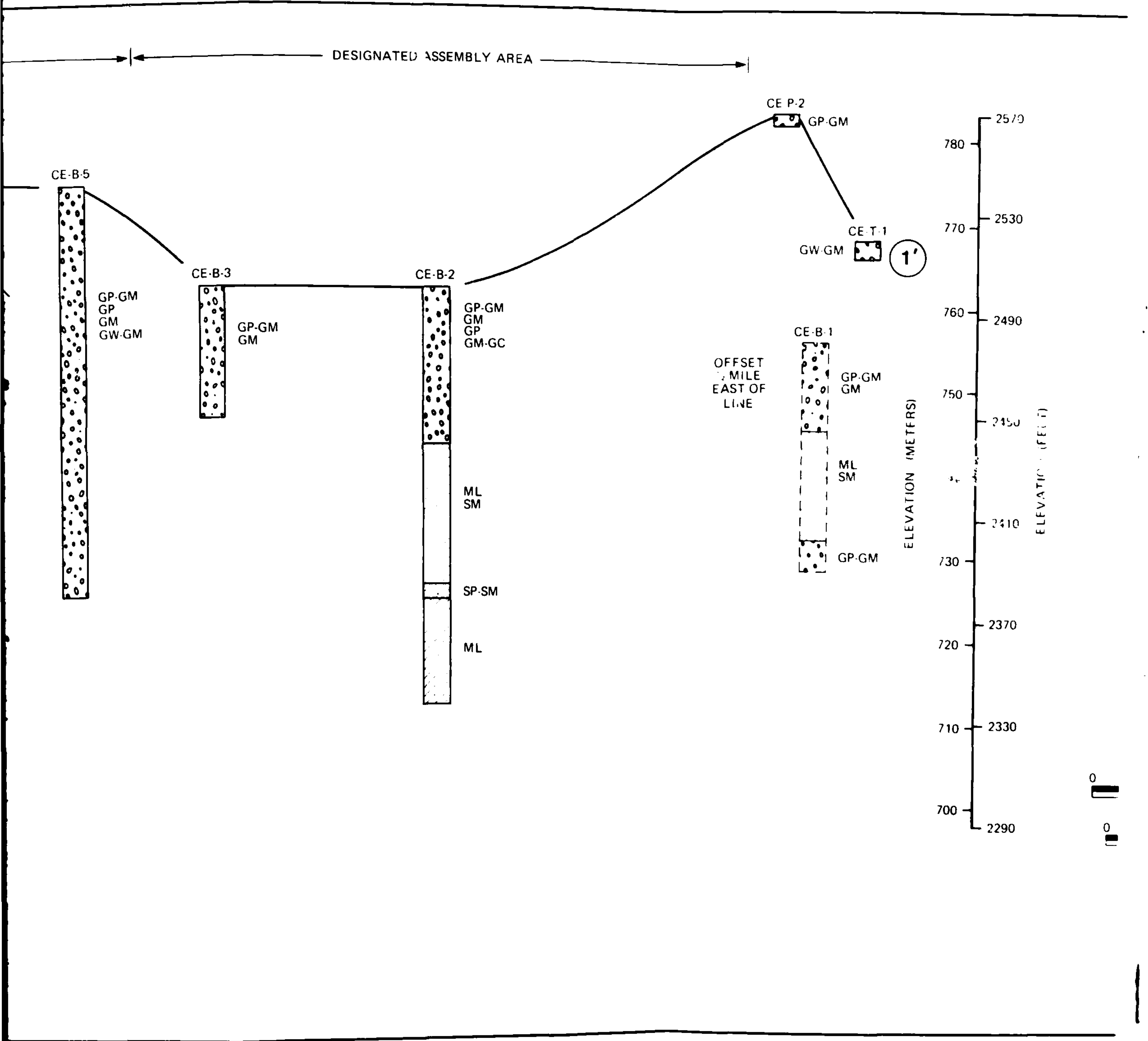
The selection of the bearing values depends on the local conditions such as cementation, density, and gradation of the soils where the structures are founded and whether the structures are settlement-sensitive or not. Where there are sand or silt lenses below the foundations, the allowable bearing values should be reduced accordingly. Continuous (strip) footings are most suitable for supporting the heavy loads

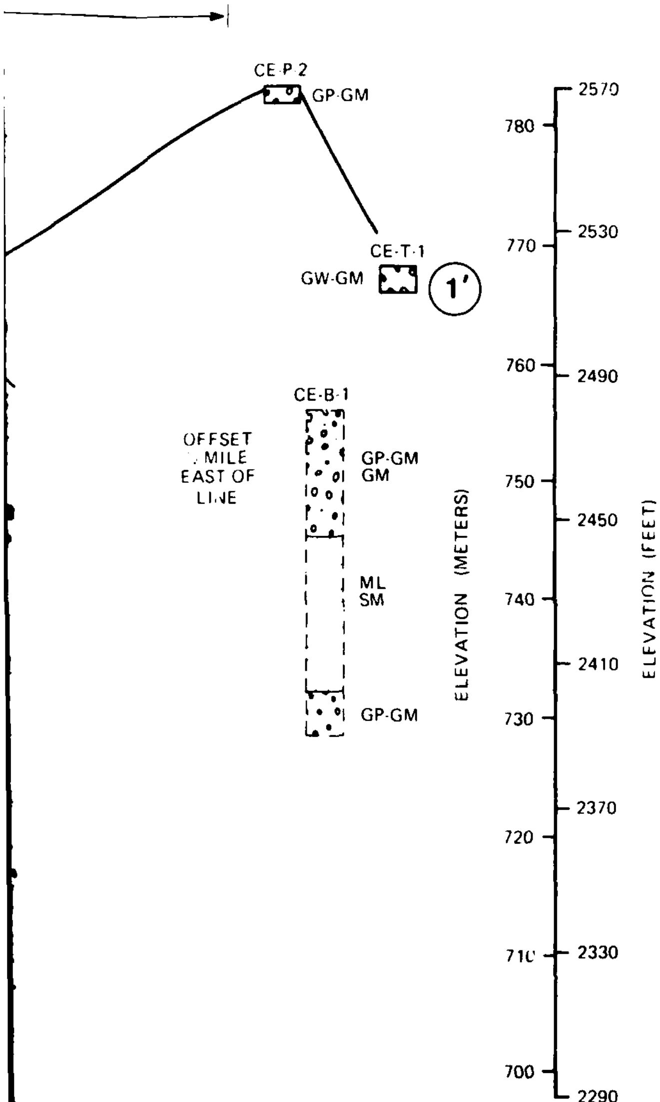
FN-TR-43



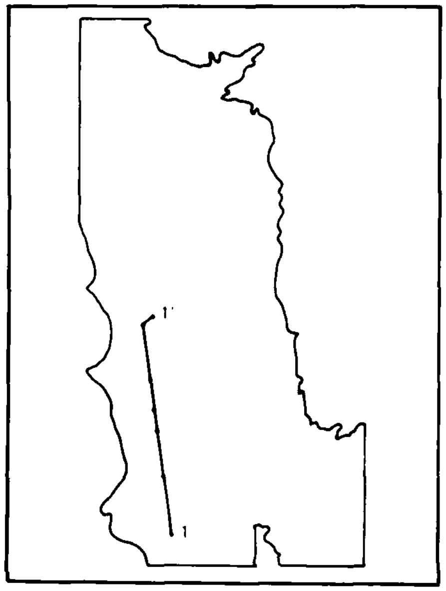
23 DEC 80

2


DESIGNATED ASSEMBLY AREA
CE-B-5
GP-GM
GP
GM
GW-GM
CE-B-3
GP-GM
GM
CE-B-2
GP-GM
GM
GP
GM-GC
ML
SM
SP-SM
ML
CE P-2
GP-GM
CE-T-1
GW-GM
1'
CE-B-1
GP-GM
GM
ML
SM
GP-GM
OFFSET
MILE
EAST OF
LINE
ELEVATION (METERS)
780
770
760
750
730
720
710
700
2530
2490
2410
2370
2330
2290
0
0



LOCATION MAP



EXPLANATION

B Boring

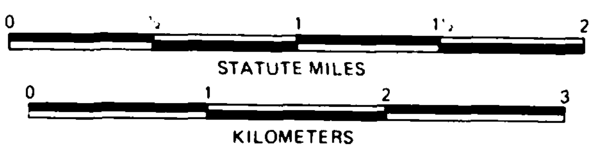
T Trench

P Test Pit

NOTES

1. Ground surface elevations shown at activity locations are approximate.
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. When two or more soil types are shown in one layer, the predominant soil type is listed first.

HORIZONTAL SCALE



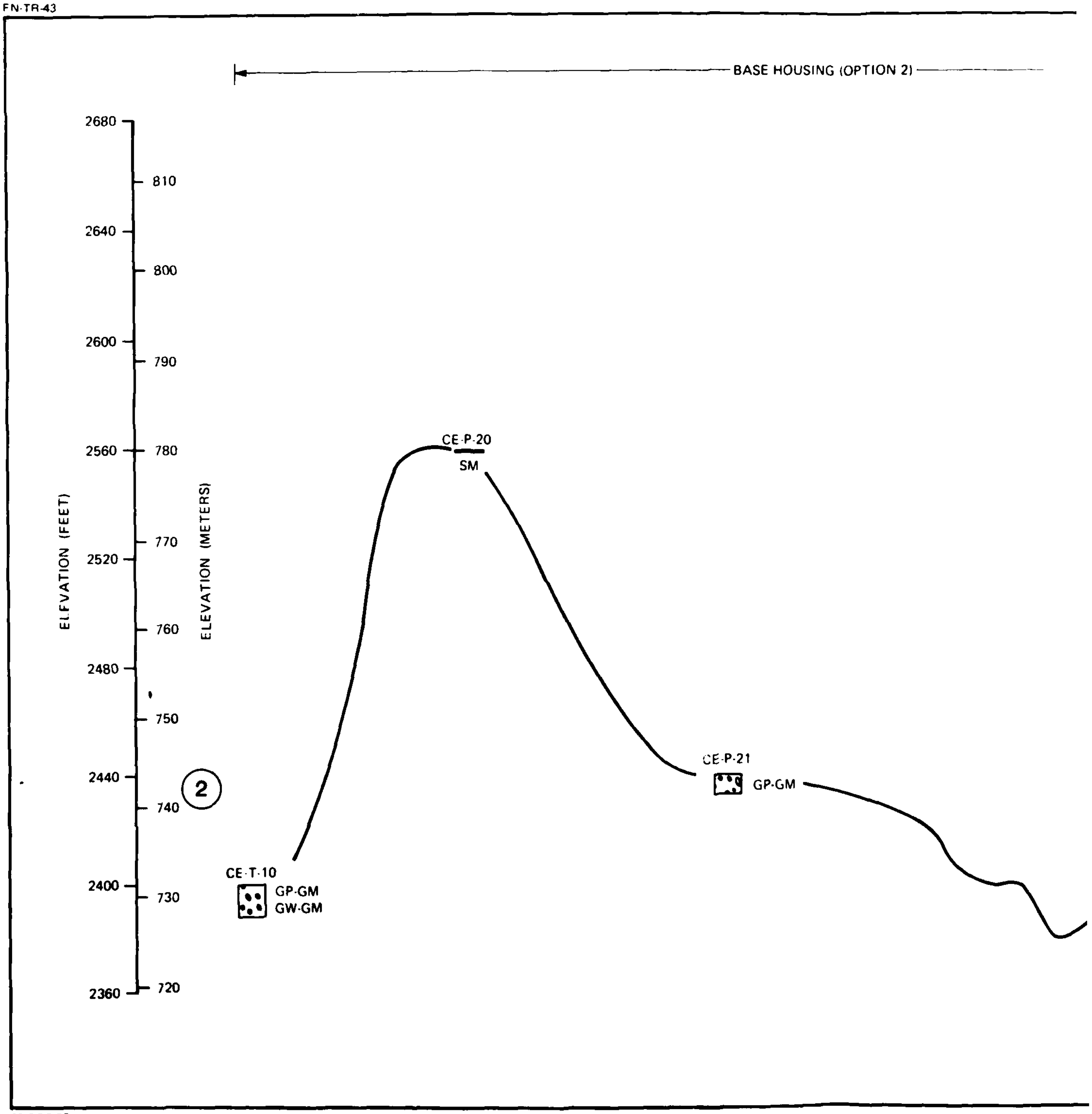
SOIL PROFILE 1 - 1'
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION

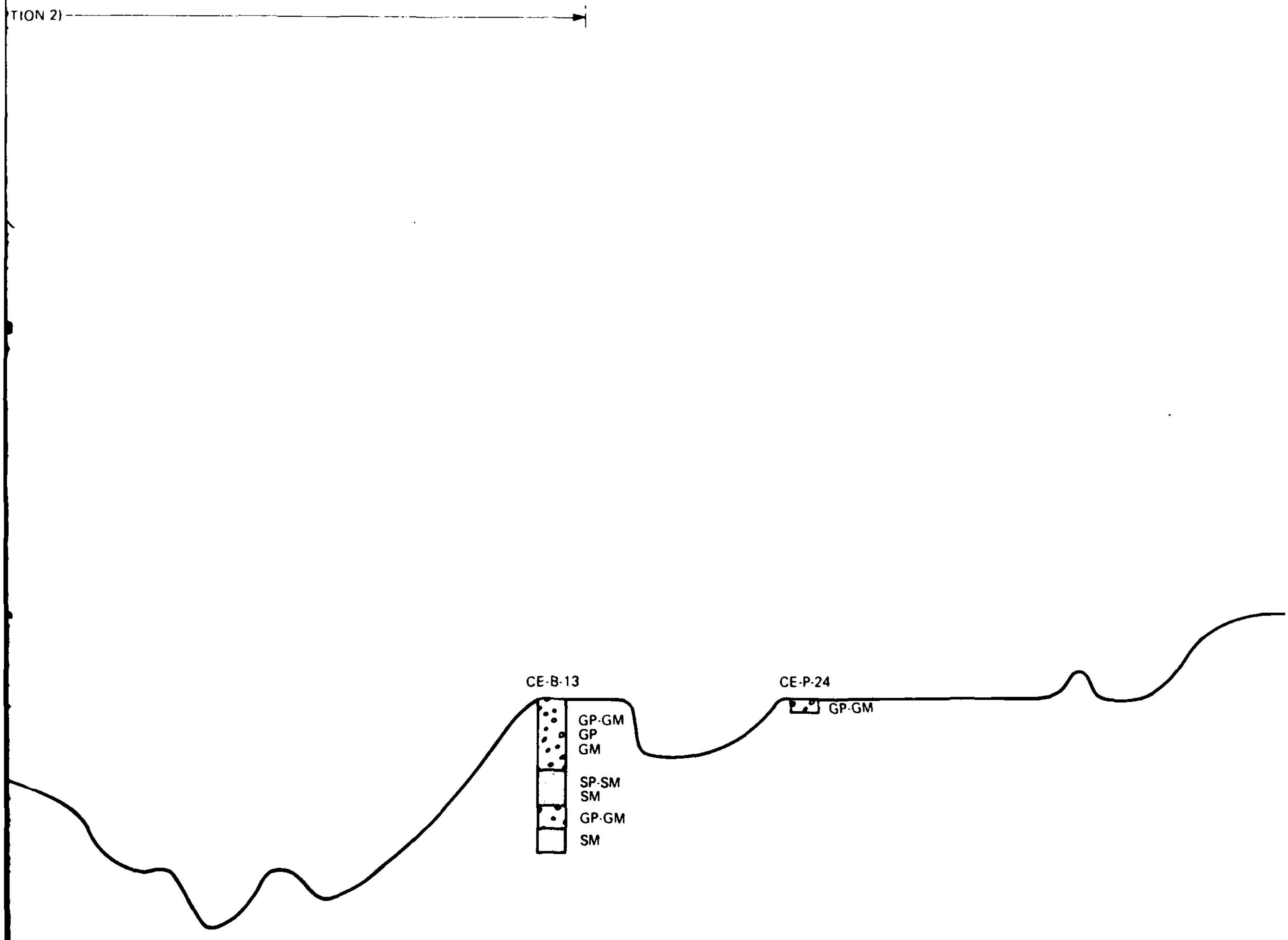
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 6-1

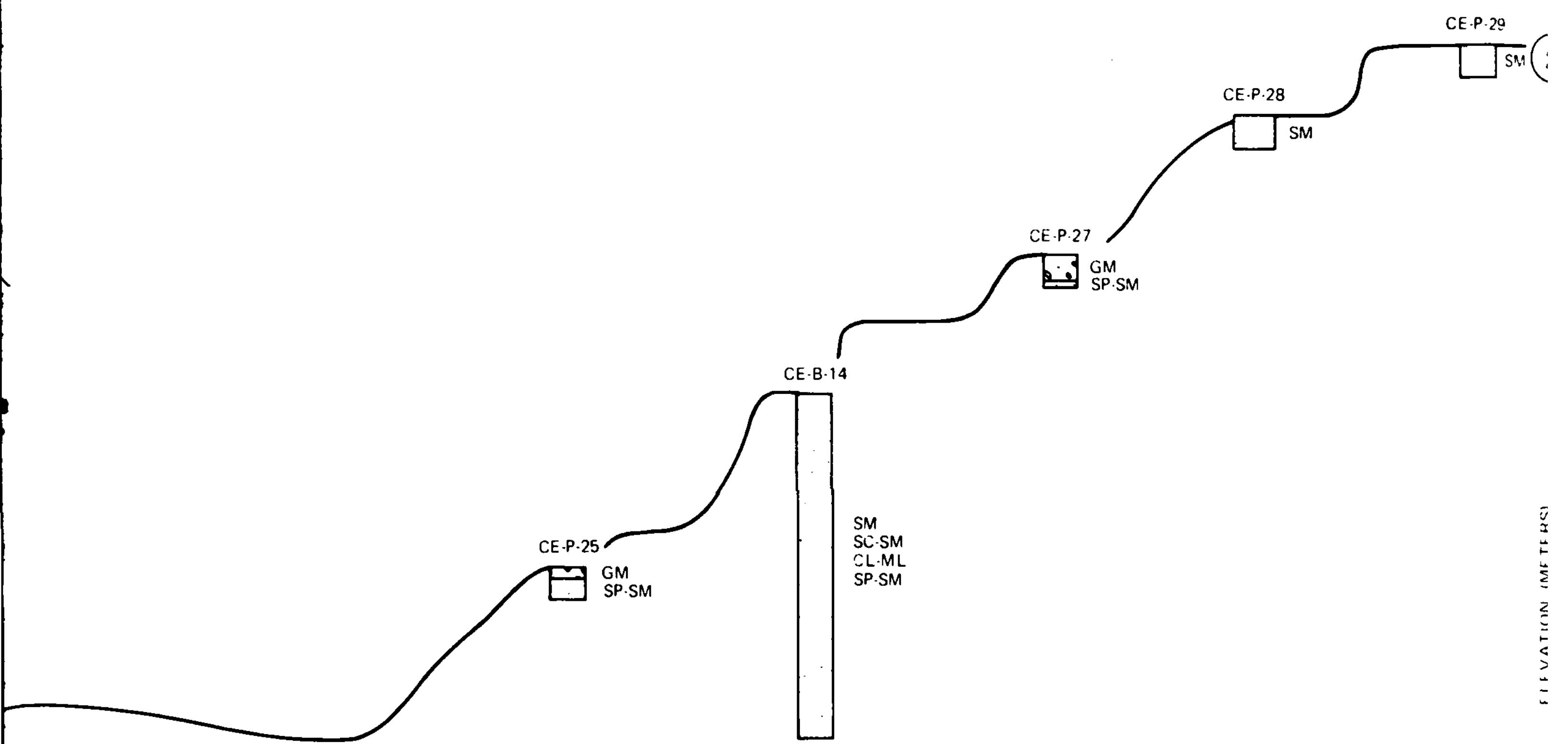
FUGRO NATIONAL, INC.


BASE HOUSING (OPTION 2)
ELEVATION (FEET)
ELEVATION (METERS)
2680
2640
2600
2560
2520
2480
2440
2400
2360
810
800
790
780
770
760
750
740
730
720
2
CE-P-20
SM
CE-P-21
GP-GM
CE-T-10
GP-GM
GW-GM

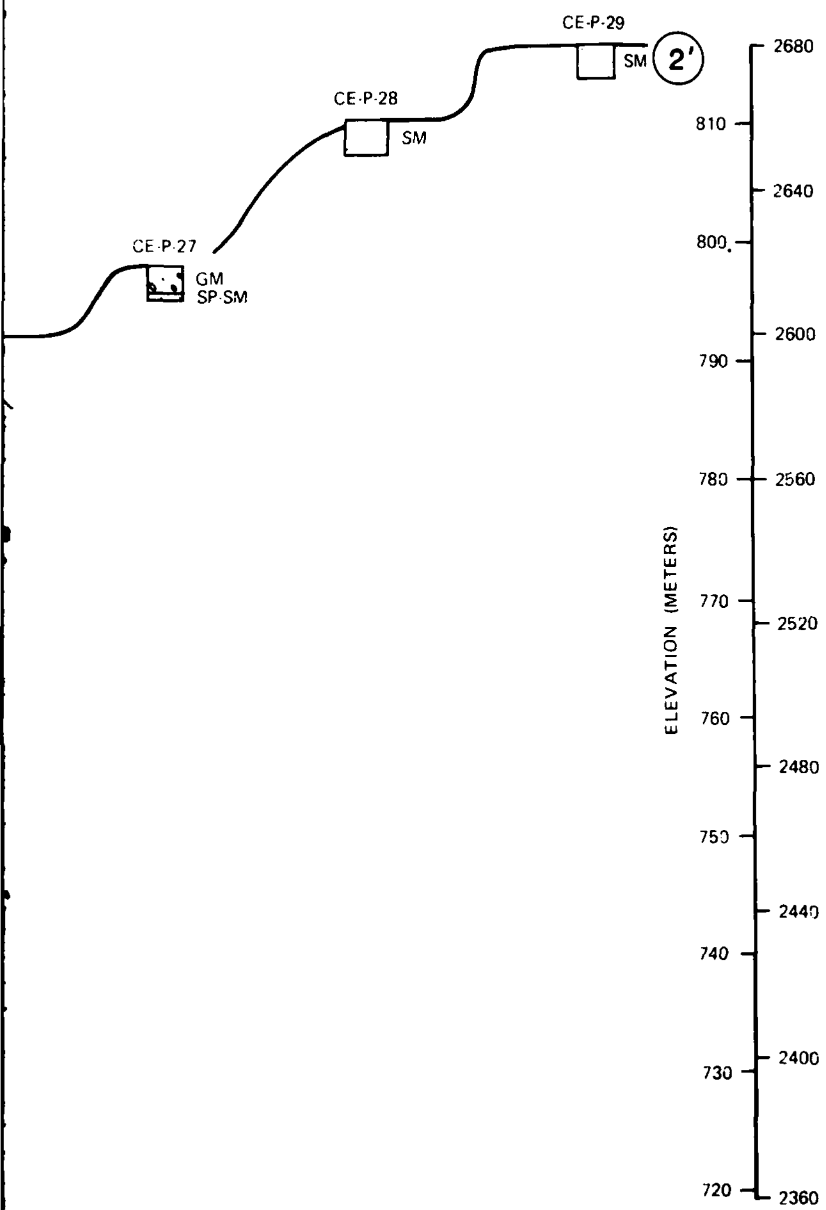
2



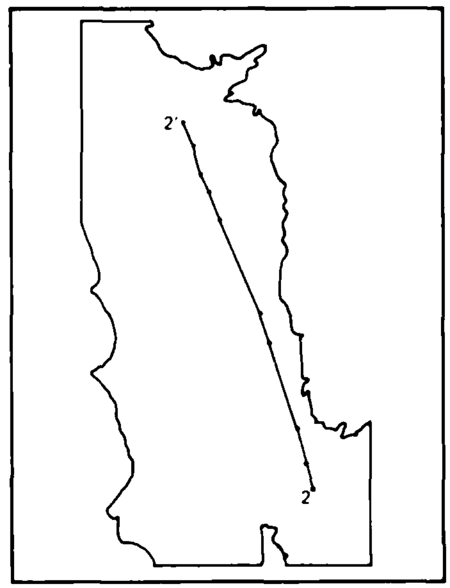
3



CE-P-29
SM
CE-P-28
SM
CE-P-27
GM
SP-SM
CE-B-14
SM
SC-SM
CL-ML
SP-SM
CE-P-25
GM
SP-SM



LOCATION MAP



EXPLANATION

B Boring

T - Trench

P - Test Pit

NOTES

1. Ground surface elevations shown at activity locations are approximate.
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. When two or more soil types are shown in one layer, the predominant soil type is listed first

HORIZONTAL SCALE

SOIL PROFILE 2 - 2'
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 6 2

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control. There is little or no effect from these shallow foundations on the sand and silt underlying the gravel.

- Slab-on-grade: For slab-on-grade construction, site preparation should consist of removing the 1 to 2 feet (0.3 to 0.6 m) of loose surficial soils. In most cases, compaction of the exposed surface should provide adequate support for the floor slab. Compaction should be 90 percent or greater as determined by the ASTM D 1557 compaction method.

  Structures with heavy floor loads such as the shallower part of the MAB, the heavy vehicle and launching assembly facilities, and the launcher integration building can use a slab-on-grade which is structurally independent of the footings supporting the walls and columns. Coefficient of subgrade reaction of 250 to 350 tcf (8304 to 11,072 tonnes/m^3) for the gravel can be used in the design.

- Foundation for Missile Assembly Building (MAB): The deeper part of the MAB consists of a 50-foot (15.2-m) deep pit with plan dimensions of 80 feet by 35 feet (24.4 m by 10.7 m) and an 80-foot (24.4-m) deep (below the bottom of the pit) shaft 8 feet (2.4 m) in diameter. The pit will be mostly in alluvial gravels, whereas the shaft will encounter predominantly sand or silt. Although the total foundation load is high, the net foundation pressure on the soils at the bottom of the pit will be small and should not pose any problem to the bearing materials of sand or silt. Spread or continuous footings placed at the bottom of the pit can be used to support this part of the structure.

  The vertical walls of the pit excavation should be supported by an adequately designed excavation support system. The support system should be designed for both the lateral earth pressure from the adjacent soil as well as lateral pressures from the footings of the structure at ground surface. The excavation for the shaft below the pit can be drilled by using a large diameter earth auger. Slurry, liners, or other measures will have to be used to support the walls of the shaft during excavation and construction.

6.3 ROADS AND RUNWAY

6.3.1 Roads

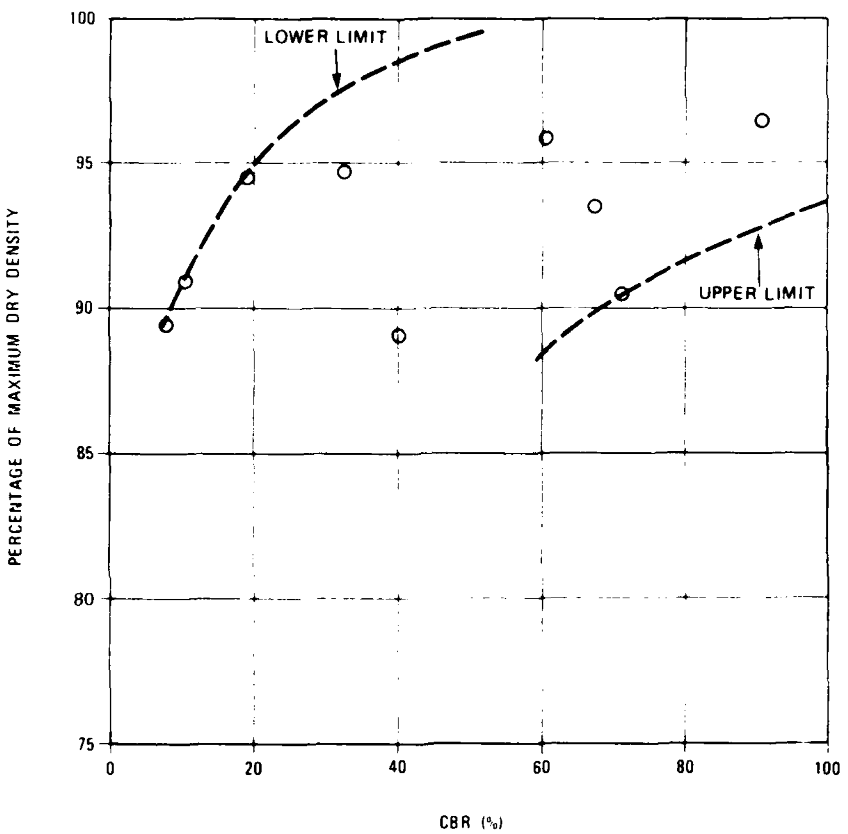
It appears that most of the roads connecting the major activity centers will be constructed on the alluvial fans consisting of sandy gravel and will provide good to excellent support as a subgrade. Only moderate compactive effort for the subgrade preparation will be required for most of these roads on the fans. The young alluvial fan deposits will probably require more compactive effort than the others.

The results of California Bearing Ratio (CBR) tests on the surficial gravelly soils are shown in Figure 6-3. The CBR value for a given relative compaction varies substantially as seen in Figure 6-3. The reasons for this are the large variation in gradation and fines content. For poorly graded gravels and those with a high fines content, the lower range of CBR values should be used for design.

Some roads will be constructed on the lake sediments consisting predominantly of silts and sands having poor to good subgrade supporting capabilities. The results of the CBR tests on silts and sands are presented in Figure 6-4.

6.3.2 Runway

As presently proposed, the planned runway would trend along the eastern edge of the MOB (Drawing 5-1). However, the southern part of this area is underlain by Tertiary lake sediments and consists in part of "badlands" terrain. The subgrade material (lake deposits) as discussed in the last section (6.3.1) is poor to good. The construction costs, resulting from additional grading work and the requirement of a granular subbase, will be higher for the lake deposits than for the alluvial gravels. It is recommended that the runway be located on the alluvial fan deposits which have more favorable subgrade



CBR VALUES FOR GRAVEL
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 6-3

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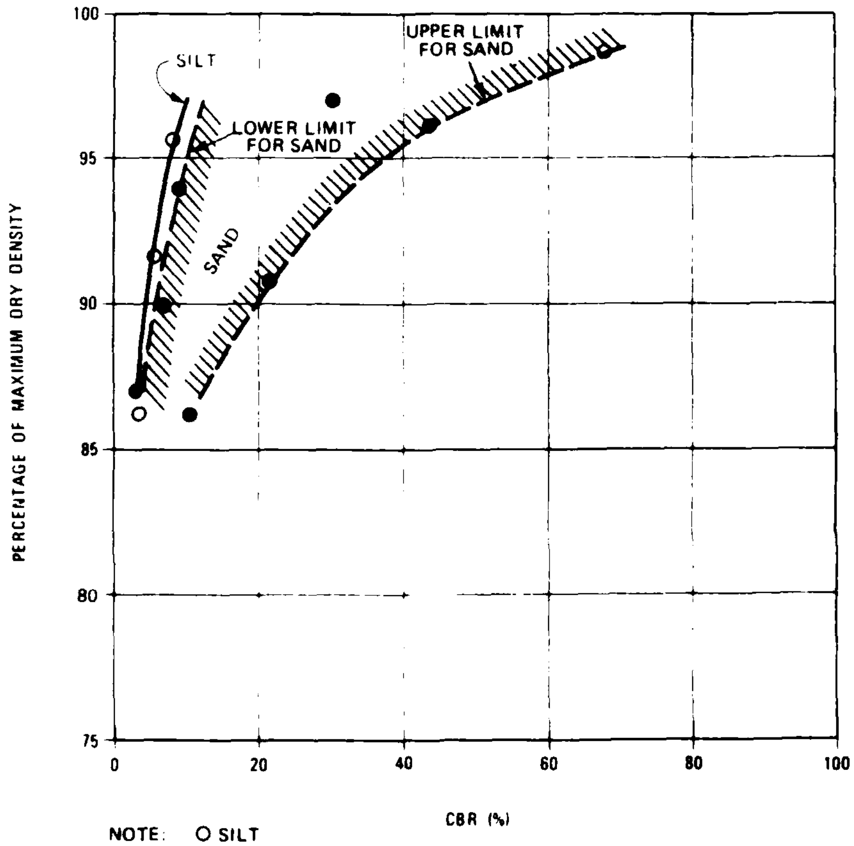


NOTE: ○ SILT
● SAND

CBR VALUES FOR SAND AND SILT OPERATIONAL BASE SITE COYOTE SPRING VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE · BMO	FIGURE 6-4

FUGRO NATIONAL, INC.

materials and terrain conditions. This requires a minor relocation of the alignment by 1/4 mile (0.4 km) westward.

6.4 SLOPE STABILITY

Natural Slopes - The natural slopes that are present at the site area appear to be stable. No evidence of any landslide or major "hillside mass wasting" was observed.

Excavated Slopes - Temporary excavations in the A5o and A5i deposits could be cut back to 1/2:1 to 3/4:1 (horizontal: vertical) because of their high degree of cementation. For cuts this steep, protection will have to be provided for workmen because of the presence of cobbles and boulders which could be dislodged from the slope. For permanent cut slopes, slope angles can be expected to vary between 1:1 and 1-1/2:1 with the steeper slope applicable only where most of the slope will be in cemented materials.

It is likely that exposed cuts in A5i and A5o gravels will become case hardened in a relatively short period of time. Case hardening is essentially a rapidly-forming surface cementation process that occurs on incision walls and which increases in thickness with time. It can develop within a few months to a point where clasts cannot be removed from the gravel by hand. After a few years, case hardened surfaces can become extremely hard. Case hardening would likely have an overall effect of improving the resistance of the slopes to erosion.

The slope angle of temporary and permanent cuts in the lake sediments will depend on soil composition and height of cut. For most materials, a cut slope of 1-1/2:1 (horizontal: vertical) will be stable; for cleaner sandy materials a cut slope of 2:1 may be required. Because of soil variations, final recommendations must be based on site-specific investigations.

Erosion - Most of the Tertiary lake sediments in the area mapped are subject to headward erosion. This is especially true in the southeastern portion of the site area near the proposed housing site. If these areas are utilized, it may be necessary to consider methods of controlling the headward erosion, such as diverting the runoff or lining the channels.

6.5 CONSTRUCTION CONSIDERATIONS

Construction aspects such as site preparation, excavatability and compactability of the soils, trenching, chemical and frost attacks, as well as drainage and erosion control are briefly discussed in this section.

- Site Preparation - The looser surficial soils, probably with weathered aggregates in most locations, should be stripped to depths of approximately 1 to 2 feet (0.3 to 0.6 m) below natural grade.

- Excavation and Compaction - The seismic velocity of the top 5 feet (1.5 m) of the subsurface soils ranges between 1360 and 2550 fps (414.5 and 777.2 mps). Based on the range of the seismic velocities and observations made during the backhoe trench excavations, conventional equipment could be used for all shallow excavations (less than 5 feet) (1.5 m). However, in areas where Stage III and IV caliche cementation exist, ripping and/or blasting may have to be used for excavation. For most of the shallow excavations, temporary lateral support is not required. However, for deep excavations, temporary lateral support will be required.

Compactability of the gravelly alluvial deposits is good. A wide range of compaction equipment will be suitable for compacting the gravel. The most efficient type will be smooth drum vibratory rollers. Compaction of the sandy and silty materials can be efficiently performed by vibratory rollers and rubber-tired rollers, respectively.

- Sulfate Attack on Concrete - Results of chemical tests indicate that the potential for sulfate attack of the surficial soils as well as subsoils on concrete will be negligible (maximum sulfate content 0.01 percent). However, gypsiferous materials in the lake sediments have been identified. The high sulfate content of these materials will be damaging to concrete.

- Frost Attack - Foundations of most of the structures will be in gravels which are not frost susceptible. However, because of grading operations and import of topsoil it will be prudent to found all footings at least 1 foot (0.3 m) below the final grade.

6.6 AGGREGATE SOURCES

Aggregate materials are commonly derived from both rock and basin-fill sources.

Ideally, a source rock of coarse concrete aggregate should be easily accessible with favorable bedding and jointing patterns. It should also possess chemical and physical characteristics that, upon mining and crushing-down, produce optimumsized equidimensional particles. Physical and chemical properties for road-base aggregate are similar but less stringent than those for concrete aggregates.

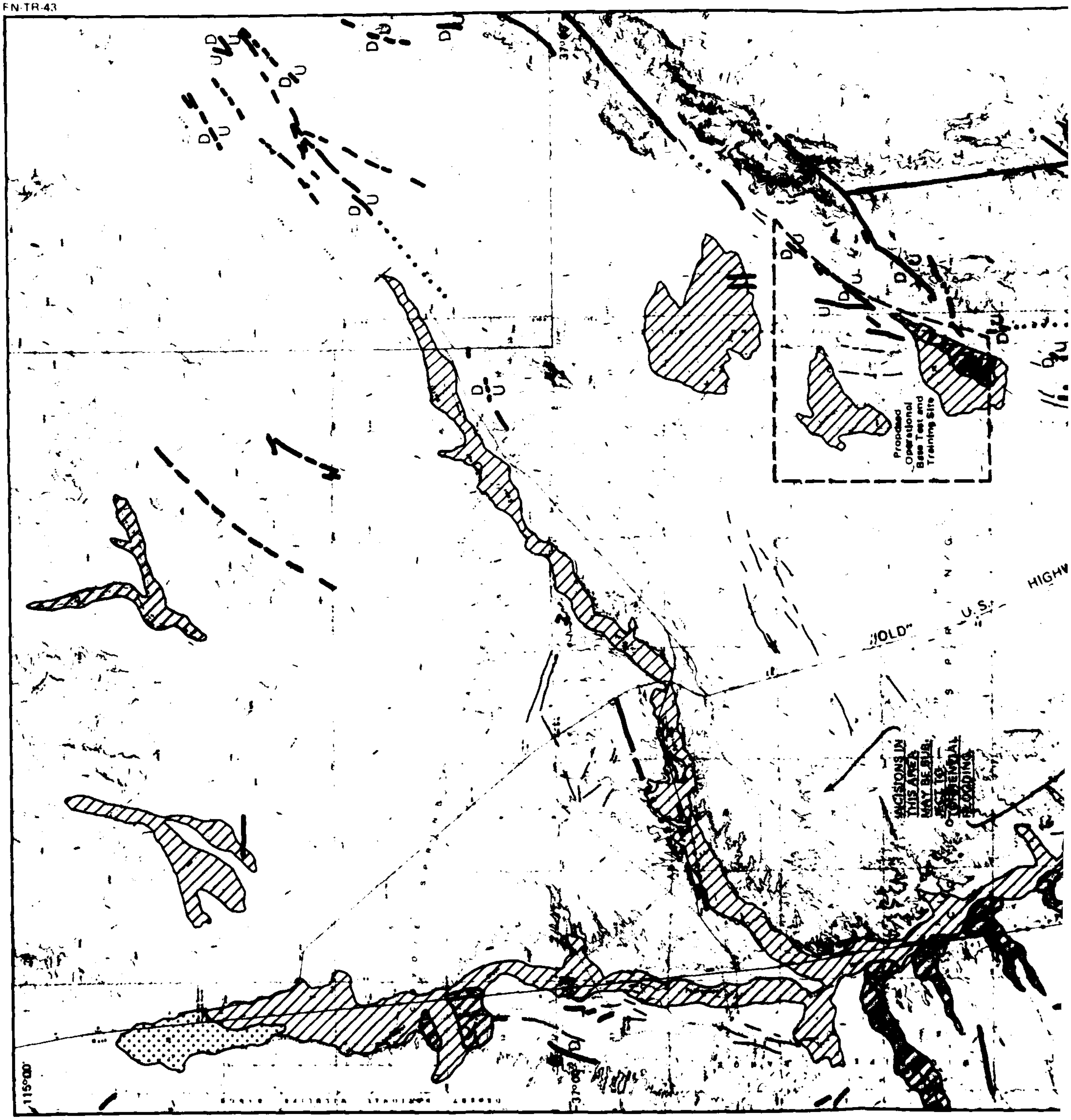
An ideal basin-fill concrete aggregate source should be composed of well graded, hard, durable, subangular to subrounded particles. Road-base material requirements are similar to but more tolerant than concrete aggregate requirements.

The principal source of potentially suitable coarse and fine basin-fill aggregates are the alluvial fan deposits (A5i and A5o) that flank the carbonate rock mountains surrounding the study area. Some of these older fans are partly or wholly consolidated, contain excessive deleterious carbonate or clay coatings and highly weathered clasts, and may be unacceptable for use as aggregates.

Potential sources of suitable crushed rock within the study area are the pre-Cenozoic limestone and dolomite carbonate rocks of the Sheep Range, which form a portion of the western boundary of Coyote Spring Valley, the southern Delamar Mountains (north), and the Meadow Valley Mountains (east).

Stream channel deposits (A1) associated with secondary and primary ephemeral streams may supply additional coarse and fine aggregates. They are heterogeneous mixtures that vary from boulders to silt and clay depending on the location in the valley area. The most durable materials are found along streams which drain the most acceptable rock sources.

In general, sufficient volumes of coarse and fine aggregate materials to satisfy concrete and road base construction purposes appear to be available from a variety of basin-fill and rock sources within the study area. However, these conclusions are based on field and visual observations with limited laboratory test data. An aggregate laboratory testing program (i.e., sieve analysis, Los Angeles abrasion, soundness, potential reactivity-chemical method, specific gravity, and absorption) is recommended before precise estimates on the quality and quantity of aggregates can be made.


Proposed Operational Base Test and Training Site
"OLD" U.S. HIGHW
115°00'

2

U.S. HIGHWAY 93
HIGHWAY 93
ROUTE
Proposed Base Housing Option 2
Proposed Designated Assembly Area
INCISIONS IN THIS AREA MAY BE SUBJECT TO TORRENTIAL FLOODING


EXPLANATION
FAULT TRACE, DOTTED WHERE INFERRED.
U: UPTHROWN BLOCK
D: DOWNTHROWN BLOCK
LINEAMENTS.
AREAS SUBJECT TO STREAM AND SHEET FLOODING, SHADED PORTIONS TEND TO FLOOD MORE OFTEN THAN UNSHADED PORTIONS.
AREAS OF POTENTIAL PONDING.
PROPOSED ACTIVITY CENTER BOUNDARY. (APPROXIMATELY LOCATED)
ASSESSMENT OF FLOOD POTENTIAL IS BASED ON GEOMORPHIC FEATURES THAT WERE FORMED PRIOR TO CONSTRUCTION OF ROADS AND HAVE BEEN ALTERED IN SOME AREAS SINCE THE ROADS WERE BUILT
NORTH
SCALE 1:62,500
0 1 2
STATUTE MILES
0 1 2
KILOMETERS
Proposed Base Housing Option 2
ROUTE
GEOLOGIC HAZARDS MAP
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO
DRAWING
6-1
FUGRO NATIONAL, INC.

7.0 RECOMMENDATIONS FOR FUTURE STUDIES

Additional detailed studies should be made prior to final layout and design of the various facilities in the OB in order to expand the data base developed during this preliminary investigation. An outline of the recommended studies is as follows.

7.1 FAULTS AND SEISMICITY

We recommend that a seismic risk analysis that includes the following be performed:

- o Seismotectonic setting and its significance;
- o Seismic history of the region;
- o Local and regional fault relationships;
- o Fault parameters (including length, projections, nature of displacement, etc.;
- o Activity ratings (ages of last movement);
- o Empirical relationships of fault length - scarp height to credible and probable maximum magnitudes;
- o Probabilistic study for future earthquakes; and
- o Recommendation for seismic design of structures.

We also recommend that trenches be excavated across some of the "lineaments" (discussed in Section 5.5.2 of this report) that trend through the planned facility sites to determine their origin and characteristics.

7.2 FLOOD POTENTIAL

An assessment of the potential for flooding should be made. The following items should be considered:

- o Volume of storm runoff;
- o Peak flood discharge;

- o Velocities of flow; and
- o Maximum probable flood (based on maximum probable precipitation with snowmelt taken into account).

7.3 FOUNDATION DESIGN

Detailed subsurface investigations consisting of borings, trenches, and test pits should be performed at the locations of the various structures in the different activity centers. The depth of investigation at any location will depend on the depth of influence by the structure above it. The field investigations should be geared to:

- o Determine the thickness of gravelly alluvial fan deposits;
- o Determine the occurrence of sand layers or lenses;
- o Determine the occurrence and nature of cementation; and
- o Obtain soil samples for laboratory testing.

Additional detailed laboratory tests should be performed to determine the strength and compressibility properties of the soils. Following the field and laboratory investigations, detailed analyses will be necessary in order to determine allowable bearing pressures for the various structures considering the type of structure, loading, and its tolerance to settlement.

7.4 AGGREGATE SOURCES

A detailed aggregate study should be performed to delineate the most promising aggregate sources. The study should consist of:

- o Field geologic mapping;
- o Excavation of test pits; and
- o Obtaining samples for laboratory testing.

The field work should be planned so that the lateral, as well as vertical, extent of the potential aggregate sources can be determined. In order to determine the quality of the aggregate, we recommend the following tests:

- Sieve analysis, Los Angeles abrasion, soundness, potential reactivity, specific gravity, and absorption.

In addition, we recommend that trial mixes of concrete using these aggregates be made in order to determine the concrete strength and related properties.

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APPENDIX

A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 12,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AGGREGATE - Granular material such as sand, gravel, crushed stone, and iron-blast furnace slag used for constructional purposes.

ALLOWABLE BEARING PRESSURE - The maximum foundation pressure to the soil which will not induce structural damage to the super-structure. The net allowable bearing pressure is the allowable bearing pressure less the original overburden pressure.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water (including mud and debris flows) as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water (including mud and debris flows) as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid Limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D 423-66).

Plastic Limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D 424-59).

Plasticity Index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of moisture content through which a soil-water mixture is plastic.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogeneous detrital material deposited in a sedimentary basin.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated surficial material. The term is also used here to include the rock composing the local mountain ranges.

BORING - A method of subsurface exploration whereby an open hole is formed in the ground through which soil-sampling or rock-drilling may be conducted.

BOULDER - A detached rock mass having a diameter greater than 10 inches (256 mm), being somewhat rounded or otherwise distinctively shaped by abrasion in the course of transport.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - Calcium carbonate ($CaCO_3$) cement.

CATCHMENT AREAS - The recharge area of a drainage basin and all areas that contribute water to it.

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 in^2 base area) (19 cm^2) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1-inch (2.5-mm) penetration.

CENOZOIC - An era of geologic time from the beginning of the Tertiary period (about 65 million years ago) to the present.

CLAST - An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering (disintegration) of a larger rock mass.

CLAST SUPPORTED GRAVEL - Gravel in which the support is provided by clast-to-clast contact instead of by an interstitial matrix.

CLAY - Fine-grained soil (passes No. 200 sieve; 0.074 mm) that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air dried.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

CLOSED BASIN - A catchment area draining to some depression or lake within its area from which water escapes by evaporation or infiltration into the subsurface.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobbles) larger than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, larger than a pebble and smaller than a boulder, having a diameter between 3 and 10 inches (64 and 256 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D 1557-70).

COMPRESSIBILITY - Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

CONE PENETROMETER TEST - A method of evaluating the in situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60° apex angle, 15-cm^2 projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally-projected area.

Friction resistance, f_s - The resistance to penetraton developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONGLOMERATE - A coarse-grained clastic sedimentary rock composed of fragments larger than 2 mm in diameter. The consolidated equivalent of a gravel.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action, the finer dust and sand are blown or washed away, leaving the larger particles explosed on the surface.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED - The cutting of stream channels into soil units by the movement (or flow) of water.

DOLOMITE - A carbonate sedimentary rock composed of more than 50 percent magnesium carbonate.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

EPHEMERAL STREAM - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

FAULT - A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture.

FAULT BLOCK MOUNTAINS - Mountains that are formed by faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (7[illegible] mm).

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FOOTING - (Spread, combined, continuous, or strip) - If various parts of the structure are supported individually, the individual supports are known as spread footings, and the foundation is called a footing foundation. A footing that supports a single column is called an individual footing; one that supports a group of columns is a combined footing; and one that supports a wall is a continuous footing.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch-(2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures and of the history of geologic changes as recorded by these surface features.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-inch (76.2 mm) sieve and are retained on a No. 4 (4.75 mm) sieve.

GYPSIFEROUS - Containing gypsum, a mineral consisting mostly of sulfate of calcium.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

JOINTS - Surfaces of fracture or parting in a rock, without displacement.

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LIMESTONE - A sedimentary rock consisting chiefly of calcium carbonate.

LINEAMENT - A linear topographic feature of regional extent that is believed to reflect crustal structure.

LIQUID LIMIT - See ATTERBERG LIMITS.

MATRIX - The finer-grained material filling the interstices between the larger particles of a sediment or sedimentary rock.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven dried weight of the sample.

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third 6 inches (0.15 m) with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D 1586-67).

NET ALLOWABLE BEARING PRESSURE - See ALLOWABLE BEARING PRESSURE.

NORMAL FAULT - A fault that dips towards the block that has been relatively downdropped (angle of dip is usually 45°-90°).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

PALEOZOIC - An era of geologic time from about 570 to about 225 million years ago.

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering (e.g., desert varnish).

PEBBLE - A rock fragment larger than a granule and smaller than a cobble, having a diameter in the range of 1/6 to 2.5 inches (4 to 64 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

PERCHED GROUND WATER - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch-(73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLIOCENE - A division of time (epoch) within the late Tertiary period (5 to 1.8 million years).

POTENTIALLY ACTIVE FAULT - A fault which has not moved during the Holocene epoch (0 to 12,000 years) but which shows geologic evidence of recurrent movement during the Pleistocene epoch (12,000 years to 1.8 million years) and remains favorably oriented to the present tectonic stress regime such that it has a potential for movement in the future.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (true, intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA (deep/shallow) - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers. This is used to map the depth to such layers.

SETTLEMENT - The subsidence of a structure, caused by compression or movement of the soil below the foundation.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SHEAR ZONE - A tabular zone of rock that has been crushed by many parallel fractures due to shear strain.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

STRIKE-SLIP FAULT - A fault on which the movement is parallel to the fault's strike.

SUBGRADE - A layer of earth or rock that is graded to receive the foundation of an engineered structure.

SUBSIDENCE - The sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion.

SULFATE ATTACK - The process during which sulfates (salts of sulfuric acid) contained in ground water cause dissolution and damage to concrete.

TALUS - Rock fragments of any size or shape derived from and lying at the base of a steep rocky slope.

TECTONICS - Related to regional structural features.

TEST PIT - An excavation made to depths of about 5 feet (1.5 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 15 feet (4.5 m). A trench permits visual examination of soil in place and evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D 2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied, directed along the axis of the specimen called the axial load.

Consolidated-drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by shearing at constant water content.

TUFF - Consolidated clastic rock material formed by volcanic eruption.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D 2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL GRADED - A soil is identified as well graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

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A2.0 ENGINEERING GEOLOGIC PROCEDURES

The geotechnical evaluation of the potential operational base area in Coyote Spring and Kane Springs valleys was conducted in two major phases, 1) a literature study, data search, and aerial photograph analysis followed by 2) extensive field mapping and field verification of site conditions.

A2.1 REVIEW OF EXISTING DATA

The literature study and data search included a review of all pertinent geological and related literature in the region surrounding the site and discussions with state and county highway personnel to assess potential geologic hazards such as flooding.

Photogeologic analysis was done primarily on color stereo photographs at a scale of 1:25,000. Black and white aerial photographs at a scale of 1:60,000 were used to complement interpretation of data.

A2.2 GEOLOGIC RECONNAISSANCE

The primary objective of the geotechnical field program was to verify and document site conditions and potential hazards. Geologic stations were established at selected locations throughout the site area. The information collected at each station included some or all of the following, depending on local conditions:

- o Detailed geologic descriptions of outcrops, with emphasis on soil types, bedding characteristics, cementation, etc.;
- o Description of surface conditions, including slope gradient, presence of desert pavement, ground cracking, vegetation, evidence for flooding, "hardness" of surface, etc.

Observations from outcrops were supplemented by observations of existing excavations (borrow pits and road cuts), and hand-dug test pits. Data obtained from engineering backhoe trenches, test pits, and hydrologic and engineering borings were incorporated in our geotechnical analysis of the site area.

Geologic mapping was done on 1:25,000-scale color aerial photos with plastic overlays. Data were compiled into three maps and two cross sections. The maps consist of a geologic map, terrain map, and geologic hazards map. Data from the aerial photo overlays were transferred directly to 1:24,000 (geologic and terrain) and 1:62,500 (geologic hazards) topographic base maps.

The data presented on the terrain map are based on aerial photo and topographic map interpretations combined with representative field measurements. Our assessment of the flood hazard, as presented on the geologic hazards map (Drawing 6-1) is based on aerial photo analysis of existing drainage conditions and limited field observations.

A3.0 GEOPHYSICAL PROCEDURES

A3.1 SEISMIC REFRACTION SURVEYS

A3.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shotpoint to recording system via an FM radio link.

The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A3.1.2 Field Procedures

"Shallow" seismic refraction lines consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points. Geophone spacing provided six intervals of 25 feet (7.6 m) at both ends of the line and 11 central intervals of 10 feet (3 m). Six shots were made per spread at locations

65 feet (20 m), 190 (58 m), and 305 feet (93 m) left and right of the spread center. The recording system was located between geophones 12 and 13.

One "intermediate" (line 1) and one "deep" (Line 2) seismic refraction lines were recorded. Line 1 was made up of three spreads each containing 24 geophones. The geophone spacing was 160 feet (49 m). Where the spreads joined, they overlapped by one spread interval. Shots were made at the center and both ends of each spread. Two recording systems were used, so recordings were made on the center spread each time a shot was made on one of the other spreads. Thus, some additional information was obtained even though the charge sizes were not large enough for energy to carry clear across two spreads.

Line 2 was made up of one spread of 24 geophones. The distance between geophones was 100 feet (30 m). Four shots were made along this line. They were between geophones 4 and 5, 9 and 10, 13 and 14, and 20 and 21. Shots were not placed at the ends of the spread because of permitting limitations.

The explosive used on the "shallow" lines was "Kinestik" which was transported to the site as two nonexplosive components, a powder and a liquid. The components were mixed in the field to make an explosive compound. Charges ranged in size from one-third to five pounds and were buried from 1 to 5 feet (0.3 to 1.5 m) deep. On the danger lines, a nitrocarbo-nitrate slurry was used. Shots ranged from 30 to 165 pounds (14 to 75 kg) of slurry. Shots were loaded in augered holes at depths ranging from 160 to 40 feet (5 to 12 m) deep. One shot was in a backhoe pit at about 4 feet (1.2 m) deep. Charges were detonated using Reynold's exploding bridge wire (EBW) detonators instead of conventional electric blasting caps. Use of EBWs provides maximum safety against accidental detonation and extremely accurate "time breaks" (instant of detonation). Relative elevations of geophones and shotpoints were obtained by level or transit where lines had more than 2 or 3 feet (0.6 or 0.9 m) of relief.

A3.1.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal distances and best fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A3.2 ELECTRICAL RESISTIVITY SURVEYS

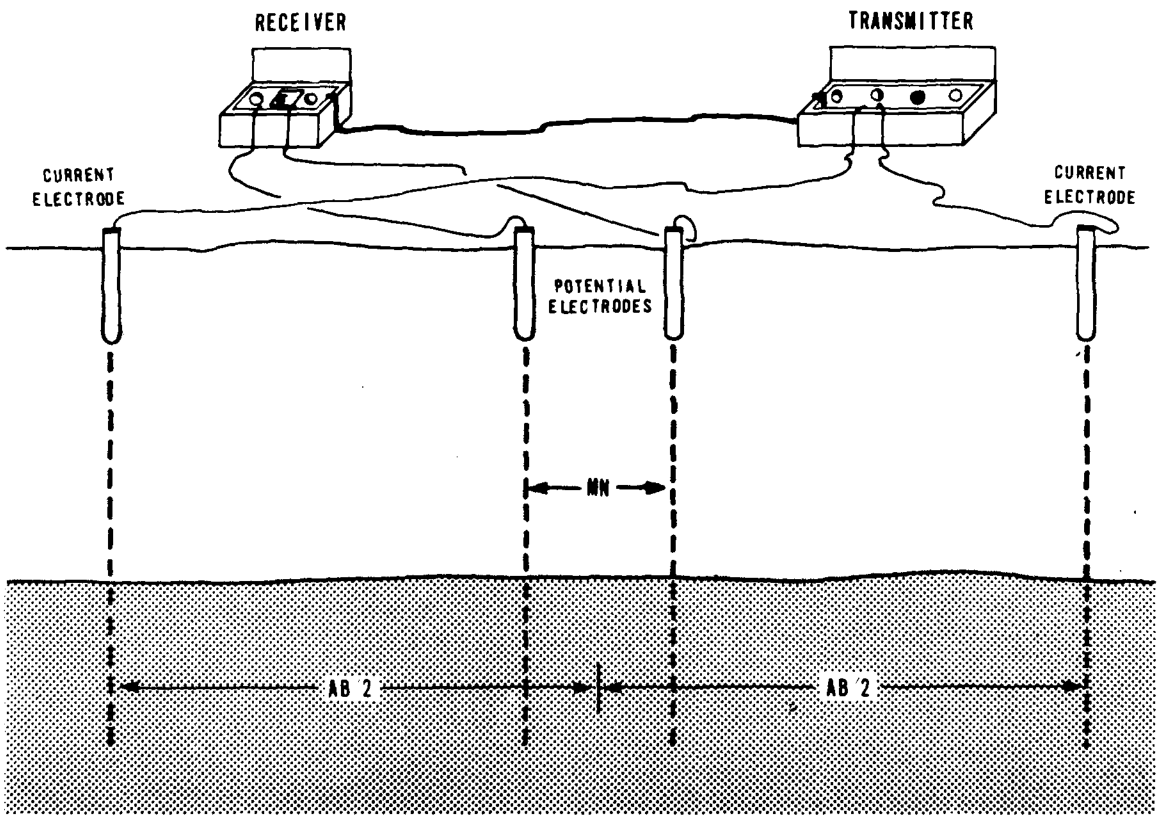
A3.2.1 Instruments

Electrical resistivity measurements were made with a Bison Instrument model 2350B resistivity meter which provides current to the earth through two electrodes and measures the potential (voltage) drop across two other electrodes.

A3.2.2 Field Procedures

Electrical resistivity soundings were made using the Schlumberger electrode arrangement. Soundings are made by successive resistivity measurements which obtain information from deeper and deeper materials. The depth of penetration of the electrical current is increased by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A3-1. The four electrodes are in a line with the two current electrodes on the ends. The distance between the current electrodes (AB) is always five or more times greater than the distance between the potential electrodes (MN).

The initial readings are made with MN equal to 5 feet (1.5 m) and AB equal to 30 feet (9 m). Successive readings were made with AB at 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 240, 300, 360, 400, 500, and 600 feet (12, 15, 18, 24, 30, 37, 43, 49, 55, 61, 73, 91, 110, 122, 152, and 183 m). MN spacing is sometimes increased one or two times as AB is expanded. This increase is required when the signal drops to a level below the meter's sensitivity. The potential drop is greater between more widely spaced electrodes (MN), so increasing MN increases the signal. When it becomes necessary to increase MN, the spacing of AB is reduced to the spacing of the previous reading. MN is then increased and a measurement is made. This provides two resistivity measurements at the same AB spacing but with different MN spacings.



SCHLUMBERGER ARRAY
ELECTRICAL RESISTIVITY SOUNDINGS
OPERATIONAL BASE SITE
COYOTE SPRING VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE A3-1

FUGRO NATIONAL, INC.

A3.2.3 Data Reduction

Each apparent resistivity value is plotted versus one-half the current electrode spacing (AB/2) used to obtain it. Log-log graph paper is used to form the coordinates for the graph. A smooth curve is drawn through the points. This sounding curve forms the basis for int preting the resistivity layering at the sounding location.

A computer program that does iterative "curve-matching" is used to develop a layer model that has a theoretical resistivity curve that is similar to the field curve. A Science Accessories Corporation "grafpen" digitizer is used to digitize the field curve for computer program input.

A4.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

- o Field activities;
  - Borings;
  - Trenches;
  - Test Pits; and
  - Cone Penetrometer Tests;
- o Office activities;
  - Laboratory Tests; and
  - Data Analyses.

The procedures used in the various activities are described in the following sections.

A4.1 BORINGS

A4.1.1 Drilling Techniques

The borings were drilled at designated locations using a truck-mounted Failing 1500 drilling rig with hydraulic pulldown and rotary wash techniques. Borings were nominally 4-7/8 inches (124 mm) in diameter and drilling fluid (typically a bentonite-water slurry) was used to stabilize the hole. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils. Nominal maximum depth drilled was 160 feet (49 m). When rock was encountered in a boring, a minimum of 15 feet (4.6 m) of rock was cored before terminating the boring.

A4.1.2 Method of Sampling

A4.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as well as at depths of change in soil type.

0' to 2'	(0-0.6 m)	- Drive sample
2.5' to 5'	(0.8 - 1.5 m)	- Pitcher or drive
6' to 8'	(1.8 - 2.4 m)	- Pitcher or drive
10' to 50'	(3.0 - 15.2 m)	- Pitcher or drive - samples at 5' intervals, starting at a depth of 10'
50' to 100'	(15.2 - 30.5 m)	- Pitcher or drive - samples at 10' intervals
100' to 160'	(30.5 - 48.0)	- Pitcher or drive - samples at 15' intervals

A4.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 335 pounds (76 kg) with a drop of 18 inches (46 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval were recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends, and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler are an outer rotating core barrel with a bit and an inner, stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Fugro Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Wash Samples: Wash samples (cuttings) were obtained by screening the returning drilling fluid during the drilling operations to obtain lithologic information between samples. Recovered wash samples were placed in plastic bags and labeled as explained previously.

d. Split-Spoon Samples: Split-spoon samplers were used to obtain disturbed, but representative soil samples. The split-spoon sampler consists of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The inside diameter of the sampler shoe is 1.375 inches (35 mm) and the length is about 18 inches (45.7 cm). Sampling with the split barrel sampler is accomplished by driving the sampler into the ground with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm). The number of blows required to drive the sampler a distance of 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value). The disturbed samples obtained from the split-spoon sampler were placed in plastic bags and labeled as explained previously.

A4.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A4.4, "Field Visual Soil Classification," of this Appendix. The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; method of drilling and sampling, drill bit type and size; driving weight; and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A4.4, "Field Visual Soil Classification," and the description was entered on the logs. Section A4.4 also discusses other pertinent data and observations made, which were entered on the boring logs during drilling.

A4.1.4 Sample Storage and Transportation

Samples were handled with care, drive spoon sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain so as not to cause any disturbance to the undisturbed samples. Whenever ambient air temperatures fell below 32°F, all samples were stored in heated rooms during the field work and transported to Fugro National's Long Beach laboratory in heated cabins in back of pickup trucks.

A4.1.5 Ground-Water Observation Wells

At designated locations, the completed boring was cased with a 2-inch-diameter (51-mm) polyvinyl-chloride (PVC) pipe to the bottom of the boring. This PVC pipe was slotted in the bottom 20 feet (6 m). Aft`r installation of the pipe, it was flushed until clear water came out. After equilibrium was reached, the water level was measured periodically in the observation wells and recorded.

A4.2 TRENCHES AND TEST PITS

A.4.2.1 Excavation Equipment

The trenches and test pits were excavated using a rubber tire-mounted Case 580 C backhoe with a maximum depth capability of 15 feet (5 m).

A4.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 14 feet (4.2 m) and lengths ranged from 12 to 20 feet (3.6 to 6.1 m). Test pits were nominally 2 feet (0.6 m) wide, 10 feet (3.0 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as was practical.

A4.2.3 Sampling

The following sampling procedures were generally followed for all trenches and test pits.

- Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet, bulk samples of both soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples (weighing about 50 pounds [11.4 kg] each) were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (1 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied tightly at the top to prevent spillage and tagged with the following information: project number; trench or test pit number; bulk sample number; depth range in feet; Unified Soil Classification symbol; and date. The samples were transported to the field office for storage and then to Fugro National's Long Beach office in pickup trucks.

A4.2.4 Logging

The procedures for field visual classification of soil encountered from the trenches and test pits were basically the same as the procedures for logging of borings (Section A4.1.3). For excavations shallower than 4 feet (1.2 m) technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. All trench walls were photographed prior to backfilling.

Each field trench and test pit log included trench or test pit number; project name, number, and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A4.4, "Field Visual Soil Classification." Section A4.4 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A4.3 CONE PENETROMETER TESTS

A4.3.1 Equipment

The equipment consisted of a truck-mounted (17.5 tons [15,877 kg] gross weight) electronic cone penetrometer equipped with a 15-ton (13,608 kg) friction cone, cone end resistance capacity of 15 tons (13,608 kg) and a 4-1/2-ton (4082-kg) limit on the friction sleeve. All operating controls, recorder, cables, and ancillary equipment were housed in the specially designed vehicle which was completely self-contained. The penetrometer, the key element of the system, contained the necessary load cells and cable connections. One end of the unit was threaded to receive the first sounding rod. When carrying out the tests, hollow rods with an outside diameter of 1.42 inches (3.6 cm) and a length of 3.3 feet (1.0 m) were used to push down the cone.

The hydraulic thrust system was mounted over the center of gravity of the truck permitting use of the full 17.5-ton truck weight as load reaction.

The cone had an apex angle of 60^{o} and a base area of 2.3 in^{2} (15 cm^{2}). The resistance to penetration was measured by a built-in load cell in the tip and was relayed to the surface recorder via cables in the sounding rods. The friction sleeve, having an area of 205 cm^{2}, was fitted above the cone base. The local friction was measured by load cells mounted in the friction sleeve and recorded in the same manner as the end resistance. The end resistance and friction resistance were recorded on a strip chart.

A4.3.2 Test Method

Tests were performed in accordance with ASTM D 3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 in/s (2 cm/s) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached.

A4.4 FIELD VISUAL SOIL CLASSIFICATION

A4.4.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (Table A4-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A4.4.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, and test pits generally included those listed below.

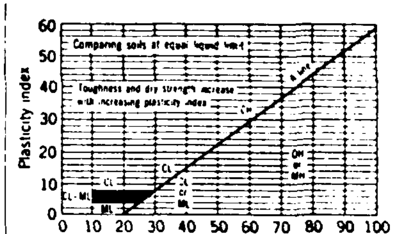
Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HC	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Major divisions			Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)	Group Symbols [a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria	
Coarse-grained soils More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel, maximum size, angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines			Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics		Atterberg limits below "A" line, or *PI* less than 4 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures			Atterberg limits above "A" line with *PI* greater than 7
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine; about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)		$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines			Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures			Atterberg limits below "A" line or *PI* less than 5 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures			Atterberg limits below "A" line with *PI* greater than 7

Identification Procedures on Fraction Smaller than No. 40 Sieve Size

Major divisions		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols [a]	Typical Names	Information Required for Describing Soils
Fine-grained soils More than half of material is *smaller* than No. 200 sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications*. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):
After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):
After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):
After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.
Highly organic clays have a very weak and spongy feel at the plastic limit.

UNIFIED SOIL CLASSIFICATION SYSTEM
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DEPARTMENT OF THE AIR FORCE - BMO

TABLE A4-1

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Following are definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations.

a. <u>USCS Name and Symbol</u>: This was derived from Table A4-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 inches (76 mm) in diameter were excluded. Fine-grained soils are those in which more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis, with the number 200 sieve (.074 mm) size particle considered to be the smallest size visible to the naked eye. In some instances, the field technicians describing the soils used a number 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the number 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (see ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. <u>Color</u>: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. <u>Range in Particle Size</u>: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. <u>Gradation</u>: Well graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. <u>Density or Consistency</u>: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease or difficulty of excavation of trench or test pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented below were also used to estimate consistency.

- o Coarse-grained soils - GW, GP, GM, GC, SW, SP, SM, SC (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

- o Fine-grained Soils - ML, MH, CL, CH (Silts and Clays)

Consistency	Shear Strength (ksf)	Field Guide
Very Soft	<0.25	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	Can be molded easily with fingers
Stiff	1.00-2.00	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	Can be imprinted with considerable pressure from fingers
Hard	Over 4.00	Cannot be imprinted by fingers

f. Moisture Content: The following guidelines were used in the field for describing the moisture in the soil samples:

Dry	:	No feel of moisture
Slightly Moist	:	Much less than normal moisture
Moist	:	Normal moisture for soil
Very Moist	:	Much greater than normal moisture
Wet	:	At or near saturation

g. Particle Shape: Coarse-grained soils

Angular	:	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	:	Particles are similar to angular but have somewhat rounded edges
Subrounded	:	Particles exhibit nearly plane sides but have well-rounded corners and edges
Rounded	:	Particles have smoothly curved sides and no edges

h. Reaction to HCl: As an aid for identifying cementation, some soil samples were tested in the field for their reaction to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. Degree of Cementation: Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of a caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

j. Secondary Material: Example - Sand with trace to some silt

Trace	5-12%	(by dry weight)
Little	13-20%	(by dry weight)
Some	>20%	(by dry weight)

k. Cobbles and Boulders: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling difficulty, by observing cuttings in borings, or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

l. Depth of Change in Soil Type: During drilling of borings, the depths of changes in soil type were determined by observing samples, drilling rates, and changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A4.5 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Fugro National's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A4.6 DATA REDUCTION

The field logs of all borings, trenches and test pits were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs generally include the following information: description of soil types encountered; sample types and intervals; lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic unit, date of activity, equipment used, and dimensions of the activity are shown on the log.

Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in situ dry strength and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location.

Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

Boring Logs	Section II - 2.0
Trench Logs	Section II - 3.0
Test Pit Logs	Section II - 4.0
Laboratory Test Results	Section II - 5.0
Cone Penetrometer Test Results	Section II - 6.0

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